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Academy of Denture Prosthetics Meeting, Detroit, Michigan, May 5 to 9, 1958.

THE JOURNAL OF PROSTHETIC DENTISTRY

VOLUME 8 MARCH, 1958 NUMBER 2

COMPLETE DENTURES
REMOVABLE PARTIAL DENTURES
FIXED PARTIAL DENTURES
OPERATIVE DENTISTRY

Official Publication of

THE ACADEMY OF DENTURE PROSTHETICS
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THE PACIFIC COAST SOCIETY OF PROSTHODONTISTS
THE AMERICAN ACADEMY OF RESTORATIVE DENTISTRY
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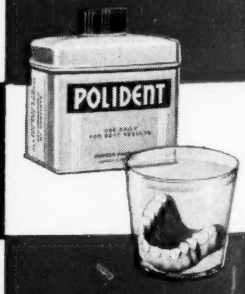

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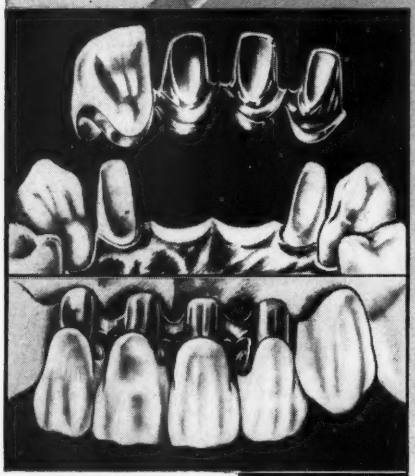

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THE JOURNAL OF
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NUMBER 2

THROUGH THE EYES OF THE EDITOR

M. M. House discusses the relationship between oral examination and dental diagnosis. He suggests a logical sequence of observations and inquiries in order to ascertain the necessary information for making a diagnosis. He recognizes the fact that the making of dentures for a patient involves much more than the mechanical fabrication of the appliances. The dentures must be properly related to the biologic factors inherent in each patient. Therefore, prosthodontics offers the opportunity for the utmost usage of the basic sciences of *any* phase of dentistry. It is unfortunate that some dentists *attempt* to "get by" with a cursory examination instead of a thorough diagnosis. Perhaps the reason is that they are making dentures rather than treating patients by supplying them with dentures. These appliances must carry out the normal functions of natural teeth *without* disturbing the health of the patient or the structures and tissues that support the dentures. The problems involved go far beyond the fabrication of the appliances. They extend into both the general and oral anatomic, physiologic, pathologic, psychologic, and nutritional conditions and require that the mechanical aspects of the appliances do not disturb these underlying biologic factors. A complete diagnosis is essential. This article suggests a sound approach to this phase of prosthodontic service.

Phil Jones discusses the characteristics of successful complete dentures and describes his techniques for constructing them. He places proper emphasis upon an accurate diagnosis. His technical procedures have been chosen on the basis of minimum complexity, and some of them may be oversimplified. It is conceivable that unlined baseplates may lead to inaccurate jaw relation records and that implicit trust in a centric relation record, made on the basis of a needle point tracing, may produce an inaccurate result because of the displaceability of the supporting tissues. It would seem that the results of these procedures should be examined critically *during* the process of building the dentures. The elimination of cusps from the teeth makes it more difficult to detect errors in occlusion or jaw relations than if teeth with cusps were used. However, the use of balancing ramps puts cusps back into the occlusal scheme even though they are placed only at the posterior ends of the arch. If these "ramps" are not harmonized with other occlusal contacts, they can be extremely destructive to the underlying supporting structures. The adjustment procedures, by grinding as guided by a central bearing grind-in device, probably eliminate many of the discrepancies which would be built into the dentures because of the "simplicity" of the technique. The occlusal adjustments, made after the dentures are completed, are probably the most important part of the technique. These must be made accurately and with intelligence.

Thomas E. J. Shanahan discusses the development of occluding surfaces of teeth which are in harmony with the physiologic factors of each individual patient. In order to do this, his recommendations are for the curvature of the occlusal surface to be based upon the development of uniform contacts regardless of

the type of closure being made. Some of his *reasons* for his objective might be questioned. For example, it seems somewhat like rationalization to say that the forms of teeth should be that of worn-out natural teeth. It is this process of *wear* that changes a curve of Spee to a reverse curve. He classifies concepts of occlusion as mechanical or physiologic. Perhaps these should be subdivided. *Some* "mechanical" techniques have exactly the same objectives as *some* "physiologic" techniques. Different methods are chosen to arrive at the same system of occluding surfaces. On the other hand, any "mechanical" system that ignores the various guiding factors of jaw movements, particularly closures in eccentric jaw positions, and any "physiologic" system that ignores the "rubbing" motions are equally wrong. Fixed condylar guidances, predetermined four-inch radius occlusal curvatures, "physiologic" occlusions set to accommodate only hinge closures, etc., *may* produce successful dentures for many patients, but many other patients would be inadequately served by dentures made on the basis of either of these *limited* interpretations of the two basic concepts. It seems a bit unfair for proponents of either system to imply that the objective of one system is to save bony foundations and that that of the other system is to destroy it. The change of the occlusal curvature from a compensating curve to a reverse curve does produce one basic change in the results. This change places a greater tipping leverage on the upper denture and reduces the tipping leverage on the lower one. The system for balancing the occlusion suggested in this article is effective when it is properly carried out, but like all other procedures, it must be done right and with a thorough understanding of the principles involved.

Joseph George Naylor discusses the jaw relations and occlusion of patients who have underdeveloped mandibles and fully developed maxillae. He suggests that these people have developed the habit of protruding the mandible in order to improve their appearance and that dentures should be constructed to harmonize with this jaw relation rather than to centric relation. He calls this semiprotruded position the median occlusal position and maintains that this relationship should be preserved constantly from the dentulous to the edentulous condition. Since the neuromuscular system is so important in establishing the centric position as well as the median occlusal position, it would seem advisable to have the occlusion in harmony in *both* jaw relations.

Ralph G. Willie discusses trends in clinical methods being used for establishing jaw relationships. In his study of this problem, he conducted a survey of the methods used by American prosthodontists, to which 110 responded. He found a wide variety of methods being used and concludes that it is unlikely that "one standard method" will ever be agreed upon. No doubt this is correct, since it is possible to obtain the correct records with any of the methods, and likewise it is possible to obtain incorrect records with any of them. The author of this article is to be congratulated since it was judged to be the best essay submitted in the 1956-1957 American Denture Society essay contest.

Clair F. Picard, Jr. discusses the appearance phase of complete denture service in his essay which won second prize in the 1956-1957 Prosthetic Essay Contest sponsored by the American Denture Society. He reviews several concepts of esthetics and combines and correlates them into an understandable unit. He is to be congratulated for his ability to co. relate these different concepts and for winning this prize.

Irving M. Sheppard discusses the effect of hinge axis clutches on the positions of the condyles. He used roentgenograms of the temporomandibular joints, made by the Updegrave procedure, for making his comparisons. He concluded that the presence of the clutches in the mouth caused errors in the records, in some instances. This problem should be given further study.

Victor H. Sears challenges "orthodoxy" and "common sense" as a means for arriving at scientific truths. He suggests instead the open mind and adequate testing of new ideas by scientific methods. It is obvious that there is merit in what he says, but there is also danger in it. Certainly, the approach he suggests is the proper one for the specialty societies. Everything should be questioned. However, while it is true that changes in established concepts are difficult to achieve, it is also true that the very existence of these established concepts prevents total chaos by providing a base line for reference and discussion. The existing concepts should not be destroyed without providing an *adequately tested* and valid substitute. The danger in his philosophy is

that some unscrupulous individuals may use it to attack established concepts which are really valid just to attract attention to themselves. The "pioneer thinker" is necessary to progress but he has an obligation to avoid "slanted" reasoning in support of his new ideas. The objective of tests and research should be "to find out" rather than "to prove."

H. A. Hartford recognizes three groups within the dental profession according to their attitude toward prosthodontics and the way in which they practice prosthodontics. He criticizes the dental teachers for this situation and says that it is enough for a student to "know how" to do a job and that it is not necessary for him to "know why." It seems that the fallacy of this premise is that he assumes that there is only one way to accomplish a given result. If a student knows "why" a certain procedure will work he can adapt other possible procedures so the desired result can be attained. If the basic principles are recognized, procedures can be developed which will be in harmony with them, and if these principles are disregarded, any technique will produce success *only* by chance.

Oliver C. Applegate discusses the interdependence of periodontics and removable partial denture prosthodontics. There can be no doubt of the importance of one as it affects the other. He calls attention to various things that happen to natural teeth which may be controlled or modified by removable appliances. If his suggestions are followed carefully, many teeth which might otherwise be lost could be saved for further long service. Also, the recognition and use of these principles could improve the reputation of partial denture service. The bad record of some partial dentures is most likely the result of a failure to follow sound principles of design, or construction, or both.

Arvin William Mann describes the impression, surveying, designing, and construction of a simple type of partial denture with distal extension bases. The attachment used is essentially an embrasure hook, and it would seem to be effective where it is indicated.

Frank H. Wallace describes his technique for making and using acrylic resin transfer copings. The procedure seems to be sound and practical. It should be particularly useful when elastic impression materials are to be used.

Edward J. Hoffman discusses the importance of considering the entire oral mechanism as a single functioning organ. In the past, this has been overlooked by some making fixed restorations. Certainly, the occlusion should be developed which would be in harmony with the jaw movements that are produced by the neuromuscular system and influenced by the temporomandibular joints. The use of *any* instrument will not assure the development of a harmonious occlusion. The intelligence with which it is used is the determining factor. However, to depend upon the "flexing" of an instrument seems to place too much reliance upon "chance" in the construction of the instrument. A "mechanical equivalent" can be achieved more consistently by solid guidances than by the flexibility of the parts of the instrument. For example, a perfect circle can be drawn with only straight lines as a guide. This is a mechanical equivalent of a compass. A flexible compass would not necessarily produce a perfect circle.

Arthur H. Morrison and Herbert W. Grinnell discuss their theoretical and functional evaluation of higher speed rotary instrumentation. They classify rotary instrumentation into four categories and make comparisons of each group. Their explanation of instrument speeds is clear and logical, and when these various instrument speeds are related to the other important considerations, their analysis becomes quite practical. It is becoming increasingly apparent that equipment providing variable rotational speeds is becoming a necessity in the modern dental office.

William Lefkowitz, Hamilton B. G. Robinson, and Harry H. Postle report their studies of the response of dental pulps to the mechanical process of cavity preparation. In this investigation, they used various means for removing tooth substance and made microscopic comparisons of the effects on the pulps at similar time intervals following the operative procedures. They suggest that *traumatic* injury is not dangerous to the pulp but that other factors, such as caries, heat, and cavity depth, are more injurious to the dental pulp.

Walter T. Colquitt discusses endodontic treatment in relation to restorative procedures. The results of modern endodontic treatment are far better than those of thirty years ago. This fact may be a safety factor for some of the current operative dentistry procedures. However, to be effective, it must be done cor-

rectly and scientifically, otherwise, endodontic treatment can be as dangerous as it was a generation ago.

G. E. Myers, G. G. Wepfer, and F. A. Peyton discuss the rubber base impression materials and report their tests of various products in this class. Their results should be of interest to all who contemplate using these materials. It is apparent that the thiokol impression materials have great potential but they are not foolproof materials. There are definite manipulative procedures which must be followed if the greatest possible accuracy is to be obtained when it is used. The various materials have a wide range of working properties and consistencies, and these factors will be of importance when a rubber base impression material is chosen for a specific purpose.

Anthony K. Kaires reports further studies of masticatory forces as they are applied on partial dentures of different designs. The test denture was a bilateral distal extension restoration, and the changes in design were effected by modifying the metal casting. The results seem to be in line with those of his previous investigations and with clinical observations.

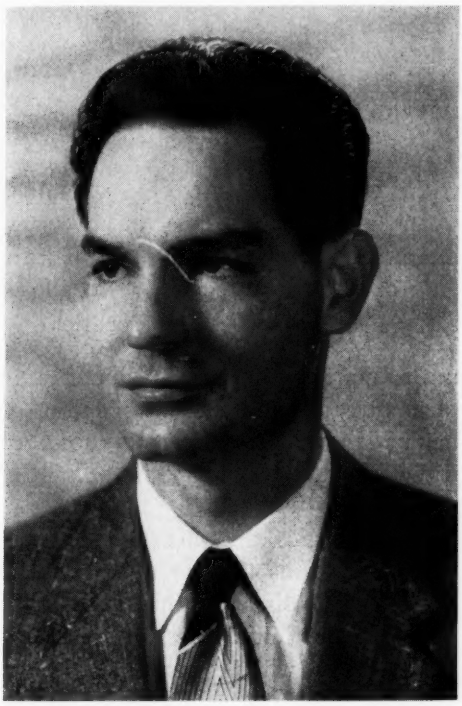
Judson C. Hickey, Julian B. Woelfel, Ralph W. Stacy, and Lloyd Rinear report on their studies of the effects of various locations of "reference electrodes" on the accuracy of their electromyographic recordings. Their results indicate that when the electrical activity of multiple reference electrodes, which are properly placed, is combined, the resultant reference is a near zero voltage point. This is an important factor to be considered when electromyographic records are being analyzed.

Paul Gibbons and Harlan Bloomer discuss the construction and application of a prosthetic speech aid for a patient with extensive pharyngeal and total palatal paralysis. The appliance is similar to those made for cleft palate patients. The effectiveness of the appliance is clearly demonstrated. This is one more example of the value of cooperation between prosthodontists and other health specialists.

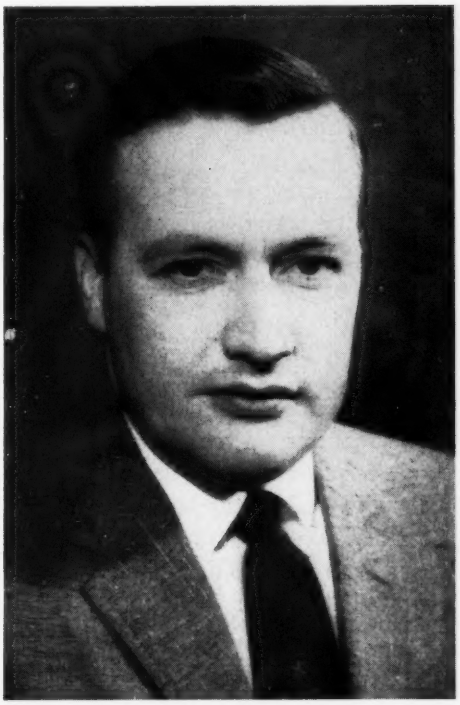
Lloyd H. Dahl describes the construction of an occlusal guide plane which can be used effectively for early orthodontic treatment of children with cleft palates. The appliance is a modified splint which makes use of an inclined occluding surface for stimulating the growth and development of the upper jaw. The forces produced by the closing muscles of mastication cause the tooth movement.

—Carl O. Boucher

AMERICAN DENTURE SOCIETY ESSAY CONTEST WINNERS



Ralph G. Willie, B.S., D.D.S.



Clair F. Picard, Jr., D.D.S.

The First Prize of $500.00 in the Fifth Annual Essay Contest sponsored by the American Denture Society was won by Dr. Ralph G. Willie of Brigham City, Utah. His essay, entitled "Trends in Clinical Methods of Establishing an Ideal Interarch Relationship," can be found on page 243 of this issue of the JOURNAL OF PROSTHETIC DENTISTRY. Dr. Willie graduated from the University of Washington, School of Dentistry in June, 1957.

The Second Prize of $300.00 was won by Dr. Clair F. Picard, Jr. of Conneaut, Ohio. His essay, entitled "Complete Denture Esthetics," can be found on page 252 of this issue. Dr. Picard received his D.D.S. degree from The Ohio State University, College of Dentistry in June, 1957.

The winners are to be congratulated on their success in winning the prizes, but the real value to them is the stimulation they have received from their own efforts. This contest is a worth-while activity of the American Denture Society, and it can lead to great careers for all who participated in it as well as to the winners.

THE RELATIONSHIP OF ORAL EXAMINATION TO DENTAL DIAGNOSIS

M. M. House, D.D.S.

La Jolla, Calif.

"The prime object of the physician in the whole art of medicine should be to cure that which is diseased; and if this can be accomplished in various ways, the least troublesome should be selected; for this is more becoming a good man, and one well skilled in the art, who does not covet popular coin of base alloy."

Hippocrates

THE VALUE OF DENTISTRY AS an important health service will be enhanced when the dental examination includes a complete study of the teeth, jaws, and other oral structures. From such a complete examination will frequently be uncovered conditions more detrimental to the health of the patient than the specific complaint for which relief may be sought.

Research workers in medicine—Billings, Rosenow, Haden, Mayo, and others —long ago established the relationship of oral conditions to general health and observed that many symptoms of serious ailments and diseases are first revealed in the mouth. Through complete dental examination, initial caries will be discovered before the pulp is involved, and oral lesions will be recognized before serious complications develop.

The procedure of examination will be more thorough when a definite method for recording data is used. It matters not what form of chart is employed for this purpose. The chart should make results of the examination readily available for reference and should constitute part of the patient's complete case history.

DENTAL EXAMINATION

A thorough dental examination includes the following information:

1. *Personal Information.*—Name, business and home address, occupation, age, general health, and name of physician.

2. *Chief Complaint.*—The average patient is usually actuated to seek dental attention by a particular complaint, systemic and/or oral. It may be discomfort, bleeding gums, esthetics, or sensitivity of the teeth to heat and cold. It may be suspicion of infection, diagnosed by a physician as the possible cause of arthritis, eye conditions, or another systemic ailment. The complaint should be determined and the patient encouraged to state its symptoms and duration. Usually the reason for seeking service has important diagnostic value.

Received for publication April 30, 1957.

The complaint of the patient who seeks denture service is worthy of note. His expectancy of esthetics, efficiency, and comfort will indicate the precautions to be observed and the patient's adaptability.

3. *Dental History.*—Note the teeth that are missing and the date of extraction. The date of extraction will reveal the patient's ability to regenerate bone. The cause of extraction is significant. If teeth have been lost through periodontal disease, the alveolar structures may still be subject to destructive processes. If the patient has had abscessed teeth, the possibility of residual infection should be investigated. To be noted is any severe reaction, pain, swelling, or "dry sockets" following one or more extractions.

The extent to which the patient has suffered from dental ailments should be carefully recorded. To be checked is the beginning of the patient's troubles and their severity—including toothaches, abscessed teeth, neuralgia, pulp stones, swelling, mucous membrane irritations, tumors or neoplasms, abnormal growths, and hemorrhage. If the patient has had pulps removed or oral surgery performed, that information should be recorded. In the event that the patient has had osteomyelitis, determine its duration and when bone repair occurred. Areas of the jaw that have not healed properly suggest that there has been incomplete elimination of pathologic tissue or that the patient is not in a state of health conducive to bone regeneration.

The patient's reaction to anesthetics, local and general, is pertinent. An unfavorable reaction after a particular anesthetic might make its use contraindicated.

Prejudices against dental treatment should also be observed. Many patients acquire idiosyncracies toward a particular dental service from personal experience or the experience or comments of some members of the family or friends. These prejudices express themselves in many ways. It may be fear of time-consuming dental treatments, unwillingness to lose natural teeth or unwillingness to save natural teeth if a great amount of inconvenience is required, the belief that careful prophylaxis wears out the teeth, prejudice against fixed or removable bridgework or complete dentures, etc. It is impossible to list the many prejudices against dental treatment which patients present. They are sufficiently frequent to warrant their investigation and the extent to which they may hamper the plan of treatment.

To be included in the history are any habits which may affect diagnosis, such as continual chewing of gum, pipe-smoking, biting of pencils, and, with children, thumb-sucking. The childhood habits of adult patients should also be noted. Occasionally, they have a relation to adult dental conditions.

The patient's past dental experiences should be thoroughly explored. Note the date of the last dental examination and the services rendered. If the patient was previously served by another dentist, the reason for his failure to return to that office should be tactfully ascertained. The patient's attention to oral hygiene and the frequency with which dental attention is sought indicate the cooperation that may be expected following the present treatment. If the patient has previously worn dentures, note the type and the length of time the dentures have been worn.

4. *Visual Examination.*—Note extraoral conditions, such as facial proportions, swelling, wrinkles, lesions of the lips, impediments in speech, and conditions of the muscles of the face, neck, and throat.

Examine carefully the cheeks, palate, tongue, gingival tissue, and buccal mucosa. Note any unusual odor of the breath. Note the teeth that are missing and determine the cause of their loss — extraction, exfoliation, congenital. Examine carefully the manner in which the remaining teeth have been restored and whether the restorations are of good quality or require removal and reconstruction. Note dissimilar metals and signs of galvanic disturbance. Note the apparent immunity or susceptibility of the patient to dental disease, the discoloration of individual teeth, the occlusion and alignment of the teeth, and their spacing. Note the wear of the teeth and the presence of sharp, rough, or abraded surfaces. Record the patient's apparent attention to oral hygiene. Learn the dentifrice that is used for its possible abrasive effect on the teeth.

In examining the gingivae, note the tone and color, as well as the presence of swellings, red spots, ulcers, and fistulous openings. Observe the condition of the interdental papillae. Gingival margins should be given special attention for food debris, salivary calculus, discharges, or bleeding.

In the throat, note unusual inflammation, mucous patches, abnormalities of the tonsils, smoker's angina, etc.

5. *Examination With Explorer.*—Examine carefully all exposed surfaces of each tooth. In order to insure thorough examination, start with the upper right second or third molar and proceed to the other side of the arch. Examine the lower teeth in the same manner.

Note the location and the extent to which the explorer enters pits or grooves. Chalky surfaces on the teeth indicate decalcification and active caries. If found at the mesial or distal ridge, these chalky surfaces suggest extensive involvement of the proximal side of the tooth. In examining the proximal surfaces, the possibility of food impaction should always be considered. In some instances, in order to complete such an examination, a separator will assist in gaining better access to these surfaces.

Examine carefully the margins of fillings and inlays. A silk ligature passed through the contact point and over the tooth will sometimes reveal defects in fillings that were not discovered with the explorer.

Following complete examination of the teeth, note carefully the condition of the periodontal tissue. Record the presence of serumal deposits below the gingivae. Record exudation of pus.

6. *Study Casts.*—If the patient has a full complement of teeth, study casts will point out irregularities in occlusion which might contribute to periodontal disease. While some of these irregularities are discovered in visual and explorer examinations, accurately prepared study casts emphasize them. With study casts, these conditions can be observed methodically without interference from the surrounding structures, such as the cheek and tongue. With study casts, the extent to which teeth are crowded or have an irregular alignment will be clearly visible, as will any abnormalities of the arches and the teeth. Damage from missing teeth, such as shifting, extrusion, and loss of contact, will be evident. Through the medium of study casts, points of premature contact in centric occlusion, points of occlusion which may cause an eccentric shift of the mandible, comparison of the inclines of posterior teeth, and areas of food impaction are easier to observe.

Study casts of the partially edentulous mouth are necessary for the efficient mechanical design of replacements. Study casts of the completely edentulous mouth vividly illustrate the form and character of the ridge.

7. *Transillumination.*—Transillumination will aid in the examination of the anterior alveolar structures and in determining cavities and lack of vitality in the anterior teeth. The amount of information that transillumination will reveal of the posterior portion of the mouth will depend upon interference from tongue and cheek and the density and volume of the structures involved.

Generally speaking, transillumination is most valuable to confirm the presence of disease in the maxillary and frontal sinuses. Transillumination of the maxillary sinus is obtained by placing the light in the mouth with the lips closed. Transillumination of the frontal sinus is obtained by placing the light in the upper part of the orbit with the eyelids closed. A healthy sinus transmits the light and a diseased sinus does not.

8. *Roentgenograms.*—Correctly made roentgenograms are extremely important *only* when they are correctly interpreted. Regardless of the direction in which the x-rays pass through the bone, they pass through two variable cortical plates. These variable cortical plates project their density upon the roentgenogram and tend to conceal conditions in the medullary portion of the bone and around the roots of the teeth. In the maxillae, the size and location of the sinuses, the height and form of the foraminal and zygomatic arches, and the density of the cortical bone must be recognized. Following observation of these anatomic structures, a systematic search should be made for unerupted and malposed teeth and pathologic conditions associated with them, abnormalities in the size, position, and number of roots on teeth, relation of the apices of pulpless teeth to maxillary sinus, changes in the pulp canal, deep caries, periapical involvement, quality of root canal fillings, evidence of resorption of hypercementosis of the root, rarefied areas, cysts, tumors, the condition of fillings and other restorations, foreign bodies, variations from normal bone, and lack of cortical bone formation over rarefied areas.

Full mouth roentgenograms of edentulous patients are essential. Investigators have shown time and again that 35 per cent to 40 per cent of edentulous patients are not ready for dentures because of the presence in the jaw of spiculae, root fragments, impacted teeth, foreign bodies, and rarefied areas. Roentgenograms frequently reveal areas of bone formation that are not conducive to comfort with dentures.

It should be remembered that impacted teeth and root fragments are always possible sources of infection. Their removal should be made dependent upon the age, health, and other conditions of the patient. If they are not removed, patients should be advised of their presence and their possible danger with an unfavorable change in health conditions.

Useful as roentgenograms are, they do not reveal infection and may or may not reveal its consequences. The extent of absorption does not always represent the extent of infection. An area of absorption of supporting tissue at the apex of a tooth may not be disclosed because it is hidden by part of that tooth, such as another root, or by a heavy mass of bone, such as the malar bone.

While pulp stones can be discovered in roentgenograms, denticles cannot. In varying degrees of their development, denticles may cause strangulation of the circulation in the pulp. Damage to the nerve and blood supply by a denticle may not be determined with a roentgenogram. What a roentgenogram does and does not show should be clearly understood. The roentgenogram does not illustrate disease. It only records changes in the radiolucency of the tissues caused by pathologic processes or surgery. Such changes in the radiolucency of the tissue furnish accurate pictures of growth and structural abnormalities. Finer pathologic conditions cannot be discovered in a roentgenogram.

9. *Mobility.*—Loosening of the teeth is an early indication of periodontal disease. The mobility of the tooth can be classified and recorded as: (1) normal movement; (2) moderate movement of the tooth acceptable to the dentist (in such instances, correction may be made if trauma or the cause of the looseness is eliminated); and (3) marked movement of the tooth, probably beyond repair.

The teeth should be tested individually with the mouth open and tested in functional occlusion. To make the test for functional occlusion, place your finger lightly over the buccal and labial surfaces of the teeth and instruct the patient to close the mouth and move the teeth in function. All teeth with a thickened periodontal membrane will show movement in the test of functional occlusion.

Light pressure over the roots of the teeth may disclose points of tenderness where the alveolar bone has been destroyed by periapical or periodontal infection.

The mobility of the teeth may be affected by the plasticity of the bone, age, and health of the patient, as well as the force applied in making the test.

10. *Vitality Tests.*—Percussion tests have a diagnostic value. A tooth in good health when tapped with a metal instrument gives a metallic sound. A tooth imbedded in infected tissue emits a dull and flat sound. Occasionally, percussion is used to test sensitivity. A tooth with pulp infection is, in acute inflammation, very sensitive to percussion or, in chronic inflammation, mildly sensitive.

Electric sensitivity varies with the vitality in the pulp. In normal teeth, sensation can be registered within certain specific ranges. Teeth in the right side of the arch will generally respond to the same quantity of electric sensation as teeth on the left side, and vice versa. Normal teeth may show a slight variation in response. Marked variations should be observed with suspicion.

Thermal tests are based on the fact that nerves in the pulp are more sensitive when the pulp is inflamed and react to the application of heat in a definite manner. If the patient presents a history of acute sensitivity to heat and cold, this test helps by the process of elimination to determine the offending tooth or teeth.

While the percussion, faradic, and thermal tests are all valuable, they are not entirely conclusive. A tooth which may be the seat of an inflamed pulp may not be tender to occlusal contact or percussion. It may, however, be sensitive to change in temperature. Yet, in certain stages of pulp inflammation and partial necrosis of the pulp, the patient may be unable to differentiate variations in degrees of heat and cold.

Age is a factor in faradic tests. Younger persons respond to lesser stimulation. The greater amount of current required for stimulation of the teeth of older people is sometimes caused by the development of secondary dentine. Some patients are hypersensitive to the test. Individuals with a fear of electric sensation occasionally respond when no current is applied. Saliva must be excluded in the faradic test. Contact with metal fillings in an adjacent tooth must be avoided by using celluloid strips or separators.

Teeth with full coverage crowns prevent proper execution of these tests. Many of these teeth that appear to be vital on the electrical test show extensive decay on removal of the crown. Many of their pulps are in an active state of decomposition. Such teeth, though normal in the roentgenogram, have proved to be a potential source of virulent infection. The rational procedure is to make vitality tests after the crowns have been removed from the teeth that are questionable.

In some instances, a so-called "nonvital" tooth in which the pulp has undergone almost complete degeneration will show fine degrees of discoloration in the enamel. Transillumination may be required to identify these variations in the darker-colored and opaque teeth.

Not all teeth respond equally well to vitality tests. Not all teeth reveal the typical symptoms that enable the dentist to make an accurate diagnosis, such as contrasting appearance of the enamel, response to pressure and percussion, and sensitivity to thermal and electric change.

11. *Special Tests.*—Conclusions reached in the dental examination will, following consultation with the patient's physician, occasionally require the support of laboratory and chemical tests and possibly animal inoculation.

Enlargement of the mouth, fissuring of the lips, a heavy, thick tongue, soft or mushy enamel, unusually large or ridged teeth, delayed dentition, and other abnormalities indicate the need for an examination for endocrine disturbances. A high incidence of caries or extensive periodontal disease indicates the need for analyses of the saliva, blood, and urine. Delayed healing following an extraction or surgery indicates the need for a blood or urine analysis. From such an analysis, a diabetic condition might be revealed as the cause of delayed healing. Diagnosis of surface lesions and exudation from a fistula or a cyst may suggest the need for a bacteriologic examination, a Wassermann or Kahn test, or even a biopsy. Observation of the tendency of the patient to bleed profusely during the explorer examination suggests a test for coagulation to determine a possible condition of hemophilia or purpura.

12. *Pre-extraction Records.*—For adults, pre-extraction records should be a regular procedure of dental examination. Note the shade, mold, and size of the patient's natural teeth and the vertical dimension of the face. Note if the teeth are excessively or moderately worn. A cast of the upper and lower anterior teeth is also desirable for future reference.

The inability to establish a cause of irritations of the mucous membrane through other diagnostic media indicates the need for allergy or dietary tests. Such tests should be considered especially when irritations appear under complete or partial dentures.

EXAMINATION OF THE EDENTULOUS MOUTH

The ideal in denture service is construction of dentures that will reproduce facial appearance and restore masticating function. How closely this ideal can be attained depends in each case on the biologic problems involved and the type of mechanical replacements supplied. Biologic conditions vary with each individual. The degree of satisfaction to be obtained with dentures will vary according to the conditions present and the extent to which they are recognized and can be accommodated in the treatment plan.

Unfortunately, the biologic contingencies of denture service have been so disregarded that the mechanical factors often overshadow everything to the detriment of all concerned. The systematic charting of biologic factors, and their proper interpretation determine the correct procedures for the mechanical phase of the work and reveal, throughout the treatment plan, the conditions favorable or unfavorable to successful service.

The numerals *1, 2,* and *3* can be used to classify biologic conditions as they are observed: (1) is favorable or normal, (2) is less favorable or medium, and (3) is unfavorable or poor. If this method of identification is understood, the recording of observations will require a minimum of time.

TONE OF THE MUSCLES OF MASTICATION AND EXPRESSION

In Class 1, the tissues are normal in tone and function. There are sufficient teeth in the mouth, and they are properly distributed to retain the normal position of the mandible to the maxillae and to furnish normal tension, tone, and placement to the muscles of power, expression, and deglutition. Degenerative changes have not yet occurred.

Except in instances of immediate restorations, edentulous patients do not have a Class 1 musculature. The majority of denture patients have experienced degenerative changes in varying degrees.

In Class 2, the tissues are slightly impaired in tone, and approximately normal functions have been preserved by the wearing of efficient dentures. "Approximately normal function" is a good description because there never can be ideal muscle tone with dentures. With the most efficient service, the pressure exerted in mastication with dentures will be considerably less than that of a normal dentition. The maximum muscular function can never be utilized once the natural teeth have been lost.

In Class 3, the tissues are greatly impaired in tone and function. It presents a subnormal condition as a result of ill health or health decline, loss of natural teeth, or the wearing of inefficient dentures. Frequently with this condition, there is an overclosure or shortening of facial dimensions. With overclosure, wrinkles in the face and a droopy mouth develop. Due to overclosure, the body of the mandible will move forward completely out of its normal range. With every degree of vertical closure, there is a proportionate degree of protrusion of the body of the mandible. Overclosure decreases the possibility of maximum power and function in mastication, due to lack of normal correct centric and vertical relations of the mandible to the maxillae, and further impairs the tissue tone of the face and muscles.

With the most efficient service possible, a Class 3 condition requires varying degrees of time in which to redevelop tone and power in the muscles and tissue. The time required will depend upon the patient's age, general health condition, nervous emotions, and the length of time over which degenerative changes occurred. It is essential that the patient be informed of the time required for correction and redevelopment.

The manner in which teeth were lost affects the tone of the muscles of mastication and expression. If anterior teeth have been missing over a long period of time, the facial expression will be markedly changed. Long absence of posterior teeth will accordingly impair the muscles used in mastication and may cause a change and pain in the temporomandibular joints.

An important function of complete and partial dentures is to form a framework with which to support the draping tissues for proper facial fullness and contour. The borders of the maxillary denture must be molded to the proper height and fullness to compensate for resorption of the labial and buccal plates and to give support and tension for the development of tone in muscles and tissue.

The intent of biologic development is the creation of the maximum leverage possible with bone and muscle. In ideal biologic conditions, the maxillomandibular dimension harmonizes with the patient's normal facial proportions. Only a normal or a Class 1 bone structure and maxillomandibular dimension will retain or develop a Class 2 tone in the function of the muscles of expression and mastication.

DEVELOPMENT OF THE MUSCLES OF MASTICATION AND EXPRESSION

The development of the muscles of mastication may be (1) heavy, (2) medium, or (3) light.

PHYSICAL SIZE OF BONY STRUCTURE

(1) The large upper and lower highly calcified bony foundations afford the greatest possible advantages for stabilizing the denture. (2) The medium-sized upper and lower bony foundations afford less advantage for stabilizing the denture. (3) The small upper or lower bony foundations with low-grade bone structure may present much difficulty in stabilizing the denture.

The *quality* of bone structure as shown by the roentgenograms is of vital importance in all classes. Any mouth may have a bony foundation of one class in the upper and of another class in the lower, according to the physical size.

With all other conditions favorable, the stability of the denture and the patient's ability to withstand biting pressure are in direct proportion to the physical size and quality of the bony structure. The patients who present the greatest difficulty are those with a large upper jaw opposing a small mandible, or vice versa. Another unfortunate condition is the presence of strong muscular development associated with a small bearing area.

ARCH FORM

While the general classification of arches as (1) square, (2) tapering, and (3) ovoid will usually satisfy the requirements of denture service, it should be

borne in mind that a fine dentition often presents the combination type of arches: (3-2) ovoid-tapering, (3-1) ovoid-square, (1-2) square-tapering, and (4) reverse-tapering.

The dentulous arch form undergoes many changes following the loss of some or all teeth or change caused by surgery or resorption. Any mouth may have an upper arch form of one class and a lower of another class.

(The numerals 1, 2, 3, 4 and the combinations do not refer to conditions as "normal," "medium," or "poor" in this instance.)

RIDGE RELATIONS

Variance of arch form and arch size in the same mouth, changes due to resorption or surgery, and varying degrees of closure alter the ridge relations. A long development of the maxillary arch with a short development of the lower arch will cause a retrusive relationship of the mandible to the maxillae. Other variances in the ridge relations may cause a unilateral or bilateral "cross-bite" relation in the posterior segments of the arch and, less frequently, a "cross-bite" in the anteriors.

Due to the development of the arch form and ridge relations, there are four possible relations of the anterior and posterior teeth. The relations of the anterior and posterior teeth govern the application of esthetics and occlusion, as well as the leverages and stresses applied in a dentition or a complete denture.

The four possible relations of anterior teeth are: (1) a normal vertical overlap of the upper anterior teeth to the lower teeth, (2) an end-to-end relation, (3) a protrusive relation of the lower to the upper teeth with varying degrees of horizontal overlap, and (4) retrusive relation of the lower teeth to the upper with varying degrees of horizontal overlap.

The four possible relations of the posterior teeth are: (1) a normal vertical overlap of the upper teeth to the lower, (2) an end-to-end relation, (3) a unilateral "cross-bite" (one side normal and the other crossed), and (4) a bilateral "cross-bite."

End-to-end relations of the posterior teeth in artificial dentures are to be avoided because cheek-biting would result.

PHYSICAL FORM OF THE RESIDUAL RIDGE

A Class 1 ridge has contours that are favorable to esthetics and efficiency in denture service. Surgical interference would not improve the conditions.

A Class 2 ridge has contours that present minor difficulties in esthetics and efficiency. A minor amount of surgery may be required, but mechanical relief may be adequate in many instances.

A Class 3 ridge has contours that are unfavorable to esthetics and/or efficiency. Surgical interference may be necessary to accomplish the most desired success. Surgery may be indicated even to obtain fair results with dentures. Abnormal growths of bone may necessitate operation before dentures can be considered. The advisability of surgery in a Class 2 or 3 depends upon the health and age of the patient and other factors.

SOFT TISSUES

Class 1 soft tissues have a normal, uniform density. The investing membrane is firm but not tense and forms an ideal cushion for a basal seat for a denture.

Class 2a soft tissues have a thin investing membrane which is highly susceptible to irritation under pressure.

Class 2b soft tissues have a mucous membrane approximately twice the normal thickness.

Class 3 soft tissues have an excessively thick investing membrane which is filled with redundant tissue.

The quality of tissue throughout the arch may vary. Tissues may be extremely thin over an area where teeth have been missing for a long period of time and normal where teeth have been more recently removed. When the tissue is alternately thick and thin or uniformly very thick or very thin, special problems are created as regards the equalization of pressure in order to avoid soreness.

BORDER TISSUE ATTACHMENTS

Border tissue attachments on the maxillae are classified as follows: (1) *high* in relation to the crest of the ridge, (2) *medium,* and (3) *low,* almost at the lower edge of the ridge.

Border tissue attachments in the mandible are classified as follows: (1) *low* in relation to the crest of the ridge, (2) *medium,* and (3) *high* almost level with the ridge crest.

Border tissue attachments are subject to change in the edentulous mouth. The degree of residual ridge resorption varies the relation of the muscle and tissue attachments to the ridge crest.

MUSCLE AND FRENUM ATTACHMENTS

Muscle and frenum attachments are classified in the same manner as border tissue attachments. In the maxillae, they are classified as: (1) *high,* (2) *medium,* and (3) *low.* In the mandible, they are classified as: (1) *low,* (2) *medium,* and (3) *high.*

The Class 3 attachments of the muscles may interfere with the seal of the denture and may require surgical correction. All lingual tissues of the mandible are classified as muscular attachments.

RETROMOLAR AREA

The tissue attachments to the mandible near the throat are classified in the same manner as other muscle attachments, i.e., according to their proximity to the crest of the ridge when the tongue is extended. They are: (1) *low,* (2) *medium,* or (3) *high.*

THE PALATAL THROAT FORM

Class 1 is large and normal in form. It has a relatively immovable resilient band of tissue, 5 to 12 mm. distal to a line drawn across the palate at the distal edge of the tuberosities.

Class 2 is medium and normal in form. It has a relatively immovable resilient band of tissue approximately 3 to 5 mm. distal to a line drawn across the palate at the distal edge of the tuberosities.

Class 3 usually accompanies small maxillae. The "curtain" of the soft palate turns down abruptly 3 to 5 mm. *anterior* to a line drawn across the palate at the distal edge of the tuberosities. Such maxillae usually have very small or no apparent tuberosities.

SALIVA

Class 1 is normal in quantity and quality. The cohesive and adhesive qualities of Class 1 saliva are ideal as a sealing medium.

Class 2 is an abundance of semiviscid, ropy, saliva.

Class 3 is excessive in amount and contains much mucus.

The insertion of dentures has a tendency to create an increased flow of saliva for the first few days or weeks of their use. This excess saliva frequently creeps under a denture and dislodges it.

Health conditions, dietary changes, and nervous reactions will vary the quantity and quality of saliva. Extensive use of the carbohydrates tends to increase the amount of mucus and the viscosity of the saliva.

TONGUE FORM

A Class 1 tongue is normal or ideal in development, size, and function. A sufficient number of natural or artificial teeth are properly distributed to maintain the normal form and function of the tongue.

In Class 2, the natural teeth have been absent for a sufficient period to permit a change in the functional action and form of the tongue.

A Class 3 tongue is excessively large. All, or practically all, of the teeth may have been absent for an extended period of time, or there may be an abnormal development of the size of the tongue. Inefficient dentures sometimes create a Class 3 condition in the functional action and form of the tongue.

RESORPTION OF THE ALVEOLAR STRUCTURES

Resorption is classified as: (1) normal, (2) excessive, or (3) incomplete. Resorption may be uniform throughout the arch or localized. It may be normal or excessive in the maxillae and incomplete in the mandible, or vice versa. Incomplete resorption suggests recent extractions.

SENSITIVITY OF THE PALATE

Sensitivity of the palate is classified as: (1) normal, (2) sensitive, or (3) hypersensitive.

TYPE OF OSSEOUS STRUCTURE

The quality of bone structure as determined in the roentgenograms is classified as: Class 1—normal, Class 2—subnormal, or Class 3—supernormal.

CONDITION OF MUCOSA

The condition of the mucosa is classified according to its health: Class 1—healthy, Class 2—irritated, or Class 3—pathologic.

SUMMARY

Until the biologic conditions revealed in the examination of the edentulous mouth are carefully interpreted and related, all diagnosis must be tentative. The biologic conditions, favorable and unfavorable to successful service, should be evaluated and then considered in conjunction with the information revealed in the patient's oral and general health history.

Conclusions reached in visual and exploratory examinations of the dentulous patient must be verified by roentgenograms and vitality tests of the teeth and, in questionable cases, following consultation with the patient's physician, by laboratory and bacteriologic examinations. Roentgenographic findings must be related to the data revealed in the vitality and other tests and to the oral and general health history. No single diagnostic medium should be made the sole basis of a diagnosis.

It should be remembered that complete and thorough examination always precedes the scientific plan for dental treatment. There are no "short-cuts" in dental examination. Cursory observation will not reveal the conditions disclosed in more careful study. Cursory examinations reveal insufficient information of diagnostic value, bear little relationship to the proper conception of dentistry as an important health service, and prevent dentistry from performing its duties as an important health service to humanity.

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A REALISTIC APPROACH TO COMPLETE DENTURE CONSTRUCTION

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A MEMBER OF OUR PROFESSION cannot help but wonder if there exists in the other learned professions so many varying opinions and so many schools of thought as we find in dentistry. In no other branch of dentistry do we find a greater variation in techniques and procedures than in the field of complete dentures. Fortunately, most of these techniques, coupled with the skill of the operator, plus the marvelous adaptability of the patient, produce successful restorations.

CHARACTERISTICS OF SUCCESSFUL COMPLETE DENTURES

A successful complete denture is one that makes it possible for the patient to speak as clearly as when the natural teeth were present, that imparts to the patient a satisfactory facial appearance, that makes possible efficient mastication, that will, as far as possible, preserve the hard and soft tissues that support the denture bases, and that can be worn by the patient with comfort. All of these are essential.

In this article, the various phases of complete denture construction will be discussed, and some of the points in each phase of construction that contribute toward a successful denture will be considered.

THE EXAMINATION AND HISTORY

One of the most important, and one of the most neglected, phases of denture construction is the examination of the patient. As in any other step, a lack of thoroughness in this phase may result in failure. Three simple things must be done to be thorough: to look in the oral cavity, to study the roentgenographic survey, and to talk with the patient. A few minutes thus spent will be much more conducive to success than is the speed with which we place impression materials in the mouth at the initial visit of the patient.

In the visual examination of the mouth, we should look for severe bilateral undercuts, hypertrophied tissue, and abnormal attachments of frenula. With the mandible in its rest position, it takes but a moment to determine if a mouth mirror can be passed between the tuberosities of the upper jaw and the retromolar pads. How much better it is to become aware of the need for surgery in this region during the examination than it is to become aware of it several appointments later after

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the casts have been mounted on the articulator. Valuable information can be obtained concerning the prognosis by noting the position of the tongue. We must be constantly on the alert for tumors of the mouth.

The roentgenographic examination will show tooth fragments, metallic objects, or unerupted teeth, if these are present in the edentulous ridges. If the presence of any of these conditions is noted, the dentist is faced with the problem of deciding whether or not surgery is advisable. It has been wisely said that the art of practice is in knowing when not to treat. This is never more true in dentistry than when one is faced with such a problem. In this regard, it is impossible to set up rules to be followed routinely. A wise decision requires a study of the many factors involved with each patient. An exception to this statement, however, can be made concerning mandibular tori. These should be removed when present for they invariably cause discomfort if the dentures are worn.

Laymen and physicians alike bemoan the passing of the old country doctor-patient relationship. It appears that the fundamental cause of this change is the inability, or unwillingness, of the physician to spend enough time talking with his patient. This same criticism can be directed at the average dentist prior to starting complete denture construction. A few minutes spent discussing the appearance of the natural teeth when they were present, the general physical condition of the patient, his attitudes, expectations, and previous denture history will yield much information that will be of great value to the dentist.

Time thus spent will result also in improvement in the appearance phase of denture construction. The information thus obtained will aid in the classification of the patient's personality, which is an important factor in the latest concepts of denture esthetics.

IMPRESSIONS

It is safe to say that no phase of denture construction has been more controversial than impressions. However, instead of considering the many different methods that have been advocated, let us consider some of the basic principles involved. Swenson[1] has given us two reasons for the maximum practical extension of denture bases: (1) to reduce the load on any square millimeter of supporting tissue, and (2) to place the borders on soft tissues, thus providing for a more efficient seal. Completed impressions should include the area to be covered by the finished dentures, no more and no less, for the dentist is in a much better position to recognize the limiting anatomic landmarks in the mouth than is the laboratory technician at the bench. With the exception of the posterior palatal seal area, the tissues should be recorded in a position of rest, rather than in a placed or displaced position. Lytle's[2] re-emphasis of the importance of providing a "recovery period" of a few days' duration to allow the tissues to return to their normal contours, after they have been subjected to the abuse of an ill-fitting denture, is important to successful denture service.

These principles are best followed by the use of trays which are constructed after preliminary impressions are made and which are lined subsequently with the final impression material. With such a method, the importance of the initial impressions is much greater than one might suspect. Unsatisfactory preliminary

impressions are usually so because of one of the following reasons: (1) the poor fit of the stock metal tray, (2) poor distribution of the modeling plaster, or (3) improper consistency of the modeling plastic due either to underheating or overheating. A large selection of stock trays is unnecessary. A set of five sizes* of aluminum trays will provide an adequate selection for almost any patient.

Frequently underextension occurs in the preliminary impression in the retromylohyoid space. This can be prevented by extending the lingual flanges of the lower tray in modeling plastic and chilling the outer layer of the modeling plastic before insertion. Since our objective is a grossly overextended impression that will include the anatomic landmarks that limit the extension of the denture borders, manipulation of the lips, cheeks, or tongue is unnecessary at this time.

One of the most critical points in denture construction is the posterior extension of the maxillary denture. Although the posterior extension can be determined later in the procedure, it seems logical to do it at the time the initial impression is made. An indelible pencil is used to mark three points on the palatal mucosa: the left hamular notch, a point two millimeters distal to the fovea palatini, and the right hamular notch. These three points are connected with an indelible pencil line, and if the dry impression is placed back in the mouth, this line will be transferred to the impression to indicate the correct posterior extension of the tray.

Various tray materials may be used. For the maxillary impression a completely satisfactory tray can be fashioned from the preliminary modeling plastic impression after it has been removed from the metal tray. Modeling plastic can be used for the lower tray, but it is less practical because the lower preliminary impression must be of a perfect thickness. For this reason, a plaster cast is poured in the preliminary impression. The locations of the limiting structures are outlined on the cast with an indelible pencil, and a tray is constructed on one of the self-curing resins. The extension of the tray determines to a great extent the extension of the denture, so this outline must be carefully determined. These limiting structures have been described by Boucher.[3]

Although pressure areas must be avoided, a tray that is relatively close-fitting seems to result in better final impressions than one made using a thick spacer between the tray and the plaster cast. This is probably due to the difficulty in centering an oversized tray. A thin layer of wax melted on the cast over the crest of the ridge, the mylohyoid ridges, and over any other sharp bony projections will provide sufficient space. There is a saving in chair time for both the patient and the dentist if one appointment is used for the preliminary impressions and another appointment is used for the completion of the impressions.

Border molding with stick modeling plastic is not necessarily a precise and exact procedure, but it does result in denture bases with a better outline form than those which are extended arbitrarily. The borders of the maxillary tray are divided into three sections. Modeling plastic is added to one section at a time. The buccal and labial borders of the mandibular tray are divided into three

*S. S. White, Nos. 102, 104, 106, 103, and 105.

sections, and the lingual flange is divided into three sections. Modeling plastic is added to each of these sections in turn. On the labial and buccal borders, the tissues are gently pulled against the warm plastic. The tongue is moved into each cheek and gently protruded from the mouth to mold the sections of the lingual flange of the lower tray.

A postpalatal seal of soft wax is added to the maxillary tray. The wax will not always show through the final impression, but it does serve to prevent excess final impression material from flowing onto the soft palate and so aids in the prevention of gagging. The anterior border of the posterior palatal seal is determined by the form of the bones forming the posterior border of the hard palate. Its thickness is determined by the amount that the tissues opposite it can be displaced. Additional seal is developed at the postpalatal seal area on the cast prior to the construction of the occlusion rims.

Before mixing the final impression material, the border molding material is reduced slightly with a knife in order that impressions of the limiting structures will be made in the final impression material. If the trays are carefully extended and the border molding procedures accurately executed, the choice of the final impression material is relatively unimportant, provided that it is a free-flowing material.

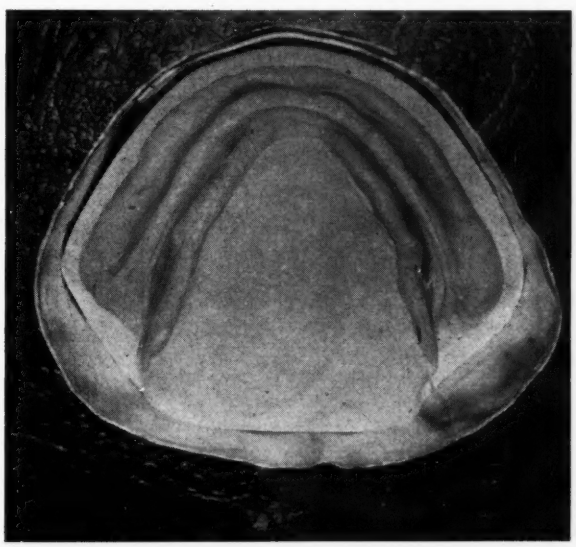


Fig. 1.—A mix of plaster and pumice and a soft metal boxing strip is used to box the impression.

It is important that the impressions are boxed before the casts are poured (Fig. 1). Considerable time and effort are spent in obtaining impressions with accurate borders. Boxing is necessary if these borders are to be preserved. Failure to box impressions seems as illogical as attempting to pour a semifluid material into a square mold that has one side missing.

JAW RELATIONS

The term "jaw relations" refers to the horizontal and vertical relationships of the mandible to the maxillae. A discussion of this phase of denture construction is simplified if we consider these two relationships individually as "vertical dimension" and "centric relation."

Occlusion rims aid in the determination of jaw relations, and the most important characteristic of occlusion rims is their adaptation to the casts. Most occlusion rims used today are constructed on shellac baseplates. While far from being the ideal material for this purpose, it is considered to be the most practical material available. If shellac bases are used they must be doubled on the borders to give them additional strength and to make them more acceptable to the lips and mucous membrane. Care must be taken to prevent warpage. If some warpage does occur, the shellac bases should be carefully readapted. A container of ice water at the chair is an aid in preventing this warpage. If these precautions are taken, it seems unnecessary to use stabilized bases. A thin layer of an impression paste and tin foil cannot prevent warpage. If warpage does occur to a lined base, the readaptation of the base becomes much more difficult. When the bases are lined with a self-curing resin, warpage may be even greater than it is with unlined bases. The accuracy of our jaw relation record is completely dependent on the fit of the trial base to the cast. Too often, this is the weakest link in the chain of procedures required for recording jaw relations.

Occlusion rims of baseplate wax are formed on the shellac bases and are used to establish the separation of the jaws and to determine the level of the anterior end of the plane of occlusion. The height of the posterior portion of the plane of occlusion can be more accurately determined after the casts are mounted on the articulator than at the time jaw relations are recorded. We are interested only in finding the location of the anterior end of the plane of occlusion, which is at the level of the incisal edges of the central incisors. Therefore, we use occlusion rims that extend only from the cuspid region on one side to the same region on the opposite side. This simplifies the process of trimming wax occlusion rims to occlude evenly.

No single pre-extraction record is more valuable than a measurement of the relationship of the incisal edges of the natural central incisors to the edge of the relaxed lips. Unfortunately, we have this information available for only a small percentage of our denture patients, so we are forced to guess when we establish the length of the maxillary occlusion rim, but it should be an *expert* guess.

VERTICAL DIMENSION

Of the many theories and principles regarding vertical dimension appearing in the literature, none is so practical or valuable as the physiologic rest position theory of Thompson.[4] It is based on the principle of the constancy of the rest position of the mandible (the vertical level of the mandible at which the elevator and depressor muscles are in balance). Whether the physiologic rest position remains constant over a period of many years, and before and after the extraction of the natural teeth, is of academic interest only. The point important

to the clinician is that for all *practical* purposes it can be considered to be constant. The weakest point in this theory is the temptation to give all patients the same amount of free-way space (interocclusal distance), when probably there is no more uniformity in this characteristic of one hundred individuals than in their shirt sizes. However, the exact amount of interocclusal distance provided is not so important as the need for providing some interocclusal clearance. Vertical dimension then appears to be like the bull's eye on the target; it permits a certain amount of variation for a perfect score. We must always keep in mind the fact that if this interocclusal gap is not provided when the dentures are made, it may be present a year or two later, but it will be present at the expense of the supporting tissues.

This determination of the interocclusal distance can be made very accurately by means of cephalometrics, if such equipment is available. It can be made also with almost equal accuracy by using adhesive tape triangles and inside calipers, as described by Pleasure.[5]

When making these measurements of interocclusal distance, it is helpful to remember that with normal patients the lips are lightly closed when the mandible is in its rest position. We must also beware lest the patient strain or force the lips together, although the rims may actually be too long, and thus give an erroneous reading on the calipers. Not only should the muscles of the jaw be at rest, but also the muscles of the lips as well should be at rest when such measurements are made.

CENTRIC RELATION

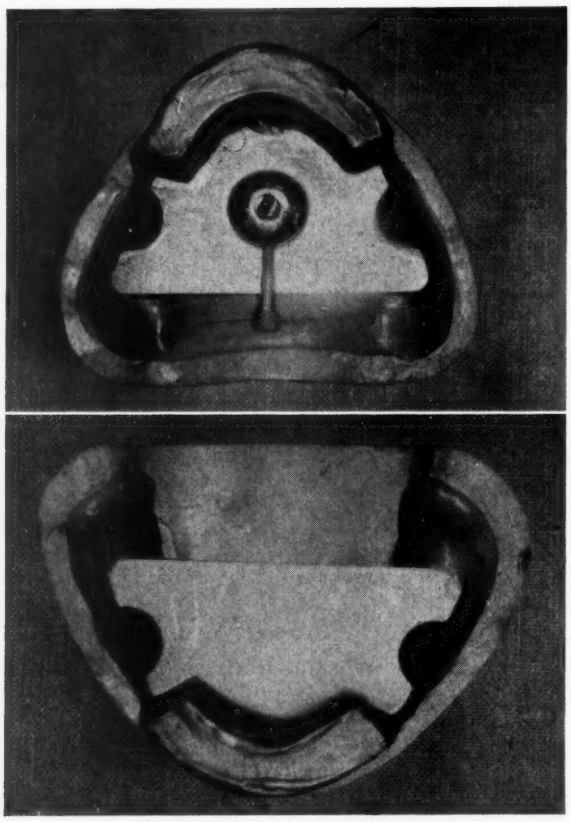
A review of the literature reveals that all of the various methods advocated for the recording of centric relation are subject to criticism. Gothic arch (needle point) tracing devices have received their full share of this criticism, usually on the basis that it is impossible in some cases for the central bearing point to be centered perfectly over both ridges simultaneously. Nevertheless, the author is in complete accord with Craddock[6] who stated that he considers the needle point tracing to be the only scientific and completely reliable method for proving centric relation.

An intraoral device, in which the stylus also serves as the central bearing point, is usually used (Fig. 2). Not only does the use of an intraoral central bearing device insure that the mandible will be in the position to meet the classic definition of centric relation, but also the registration will be made with a slight amount of closing force equitably distributed over the supporting areas.

After the vertical dimension of occlusion has been established with the anterior wax rims, the intraoral central bearing stylus is adjusted to contact the lower graph plate. A slight amount of wax is removed from the occlusal surface of the lower occlusion rim in order that the only point of contact between the two occlusion rims will be at the central bearing point. The anterior wax rims should not touch, and there should not be any contact between the baseplates in the region of the retromolar pads and tuberosities. Such contacts make it mechanically difficult for the patient to make the various necessary mandibular move-

ments, and they will destroy the effectiveness of the central bearing point. Black wax from a carpenter's crayon can be melted onto the graph plate. After the needle point tracing is formed, the graph plate is slightly indented at the apex of the tracing with a No. 2 round bur. Then, after the patient is instructed not to exert any horizontal force on the occlusion rims, the plaster maxillomandibular record is made when the central bearing stylus is in the indentation in the graph plate. The plaster for the record is injected with a Stansbery plaster gun.

A.



B.

Fig. 2.—The occlusion rims are built up only in the anterior region. The intraoral tracing device is attached to the shellac record bases.

The process of recording jaw relations is not completed until the casts are mounted on a suitable articulator. The type of articulator used is not considered to be of great importance, but its one requirement is to *maintain* the casts in centric relation after they are mounted. Since it meets this one requirement, the barn door hinge articulator, designed by Dayton Dunbar Campbell, is considered to be adequate although it is less convenient than some others.

During the set-up, we are concerned with the occlusion of the teeth in one position only, the centric position. The vertical dimension of occlusion is never

changed on the articulator; therefore, the casts are mounted arbitrarily without regard for their relationship to the hinge axis of the instrument. Condyle paths are set at an average inclination, and no further adjustment of them is made.

THE APPEARANCE PHASE OF DENTURE CONSTRUCTION

The most popular subject for discussion today in complete denture construction is esthetics. It will not be discussed completely in this article, but the following observations seem pertinent. (1) Esthetics is of extreme importance to patients, even to those who pretend an indifference. (2) The kind of anterior teeth used is not as important to denture esthetics as are the correct jaw relations, the proper division of the interridge space, and the correct positioning of the teeth. (3) More is involved in esthetics than simply instructing the commercial dental laboratory to tint the denture bases and to use prominent carvings on them. (4) Food traps and unhygienic areas should not be created in the denture bases in our attempts to produce a good esthetic result. (5) Regardless of the importance placed on prosthetic dentistry, a patient's entire personality is seldom remolded simply by inserting new dentures.

THE POSTERIOR OCCLUSION

The orthodox concept of complete denture occlusion is being challenged today as never before. Evidence is accumulating each year which indicates that noncusp teeth provide greater patient comfort. There seems reason to believe that the use of noncusp teeth contributes to the long-range preservation of the residual ridges.

One characteristic of living tissue is change. There is a gradual but inevitable reduction in the height of the residual ridges throughout the life of the patient, whether artificial dentures are worn or not. Granting that a time-consuming, complicated technique that involves multiple jaw records, hinge axis determinations, and the use of steep cusp teeth that are carefully set up may produce dentures with perfect occlusion in centric relation and perfect bilateral balance in protrusive and lateral excursions at the time of their insertion, how long will these conditions be maintained? The slightest change in the vertical height of the residual ridges results in cuspal disharmony with accompanying tissue trauma and destruction.

A cuspless occlusion permits slight changes in the relationship of the maxillary and the mandibular dentures without resulting in cuspal disharmony. If the posterior teeth are made of a material that will wear away with slight abrasion, premature contacts that may develop as the dentures are used tend to be self-eliminating.

Sears[7] has shown that, for maximum denture stability, the ideal position for a posterior tooth is in the exact center of the denture. While this is obviously impossible, the closer this point is approached with the working occlusal units, the greater will be the stability of the lower dentures.

The method taught by Hardy[8] for setting posterior teeth places them in the proper relation to the ridges buccolingually and produces an occlusal plane that is parallel with the mean foundation plane. Occlusal forces thus tend to seat, rather than unseat, the lower denture, and the forces are directed at right angles

to the support. Bilaterally balanced occlusion within the functioning range is provided by the use of a balancing ramp. This usually consists of a lower second molar that is tilted upward and forward at its distal end to an arbitrary 30 degree angle with the occlusal plane. Maxillary second molars do not function in balanced occlusion and, in keeping with our objective of centralizing forces, they are left a millimeter or two out of occlusion or they can be omitted entirely.

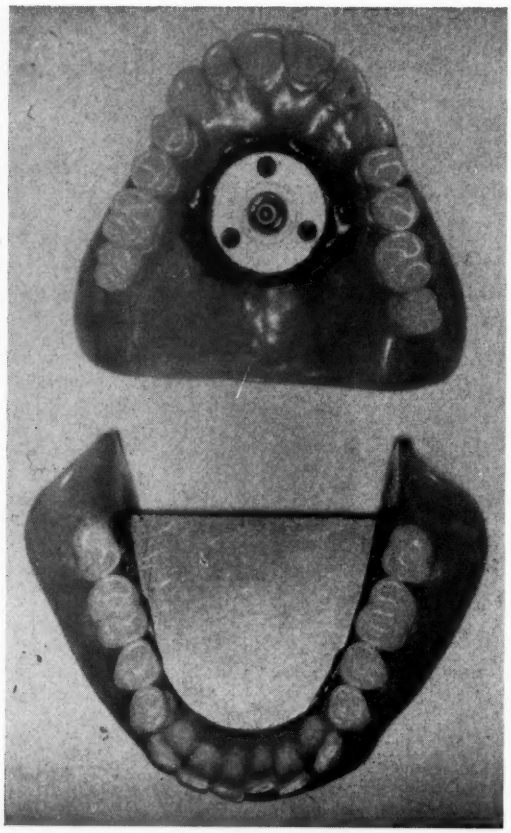


Fig. 3.—The central bearing device is attached prior to the insertion of the finished dentures.

A discussion of the try-in will be omitted from this article except to mention that, with the occlusal pattern as described, the pitch of the balancing ramps should be checked at this time. The ramps should be slightly steeper than necessary to maintain contact with the disto-occlusal angle of the upper first molars in protrusive and lateral excursions to provide for bilateral occlusal balance.

DENTURE BASE MATERIALS

In spite of its curing shrinkage, warpage, and water absorption, properly cured methyl methacrylate has proved to be a most satisfactory denture base material. Its greatest advantage is its compatibility with the oral mucosa. In the

clinic at the University of Kansas City, School of Dentistry where, during a period of seven years, over fifteen thousand complete dentures were constructed, not a single patient was observed who showed a sensitivity to the resin. This advantage is lost if self-curing resins are used, and evidence indicates that they result in dentures that are less dimensionally stable.[10] The desirability of remounting the cured dentures on their original casts to permit a correction of the occlusal changes occurring during processing appears obvious. This is made possible by previously indexing the bases of casts when they are poured.

INSERTION

At the time of insertion, the dentures are checked for stability, retention, and border extension. The pitch of the balancing ramps is correlated with the condylar paths of the patient by using either a Hardy or Coble central bearing grind-in device (Fig. 3). At the same time, any areas of premature tooth contacts are reduced. The patient should be given appropriate instructions, preferably printed, and an appointment within twenty-four hours after insertion should be made for observation and adjustment if necessary.

CONCLUSION

Some of the factors pertinent to successful complete denture construction have been discussed. A method of denture construction that, in the words of Porter,[9] favors "simplicity" over "complexity" has been described.

REFERENCES

1. Swenson, M. G.: Complete Dentures, ed. 3, St. Louis, 1953, The C. V. Mosby Co., p. 85.
2. Lytle, R. B: The Management of Abused Oral Tissues in Complete Denture Construction, J. Pros. Den. **7**:27-42, 1957.
3. Boucher, C. O.: A Critical Analysis of Mid-century Impression Techniques for Full Dentures, J. Pros. Den. **1**:472-491, 1951.
4. Thompson, J. R.: The Rest Position of the Mandible and Its Significance to Dental Science, J.A.D.A. **33**:151-180, 1946.
5. Pleasure, M. A.: Correct Vertical Dimension and Freeway Space, J.A.D.A. **43**:160-163, 1951.
6. Craddock, F. W.: Prosthetic Dentistry, ed. 3, London, 1956, Henry Kimpton, p. 127.
7. Sears, V. H.: Principles and Technics for Complete Denture Construction, St. Louis, 1949, The C. V. Mosby Co., p. 104.
8. Hardy, I. R.: Technique for Use of Non-anatomic Acrylic Posterior Teeth, D. Digest **48**:562-566, 1942.
9. Porter, C. G.: Simplicity Versus Complexity, J. Pros. Den. **2**:723-729, 1952.
10. Skinner, E. W., and Jones, P. M.: Dimensional Stability of Self-Curing Denture Base Acrylic Resin, J.A.D.A. **51**:426-431, 1955.

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THE INDIVIDUAL OCCLUSAL CURVATURE AND OCCLUSION

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IN ORDER TO ASSURE THE HEALTH of the tooth-supporting tissues against traumatic occluding forces, the occlusal curvature and the occlusion should be in harmony with the functional as well as the nonfunctional occlusal movements.

In a normal ridge relationship with natural teeth, the lateral and protrusive occlusal movements tend to retain the original concave (when viewed from above) curve of Spee of youth in a buccolingual direction.

The chewing movements, on the other hand, tend to change the curve of Spee to a convex (when viewed from above) reverse curve[1] in a buccolingual direction. This tendency to change from a curve of Spee to a reverse curve is brought about by wear. "The degree of wear depends upon several factors including the abrasive elements in the food, the hardness of the enamel and dentine, and the chewing habits, which may be modified by caries, extractions, etc."*

Similar changes of occlusal curvatures may occur in complete dentures with plastic teeth after several years of wear (Fig. 1). In both instances, the supporting tissues generally remain healthy because the necessary adjustments take place on the occlusal surfaces. According to Moses,† "The angle of wear depends on the relative widths of the mandible and the maxilla or portions thereof."

Since patients chew and rub their teeth together at various times during the day, the occlusal plane or curvature that a patient has developed through wear is used for occlusal rehabilitation. The individual occlusal curvature is preferable to a curve of Spee or a flat plane because it has been conformed, at least in part, to the rubbing and chewing occlusal movements (Fig. 2).

In complete dentures, it is just as desirable to develop an individual occlusal plane or curvature that is in harmony with the rubbing and chewing movements as it is to make individual impressions.

PHYSIOLOGIC APPROACH

The physiologic approach to occlusion and the occlusal plane or curvature may be stated as follows: The occlusal surfaces should be conformed to the functional occlusal movements of swallowing saliva and to the chewing cycles as well as to the nonfunctional lateral and protrusive occlusal movements of bruxism in order to form an individual occlusal curvature for preserving the health of the tooth-supporting tissues.

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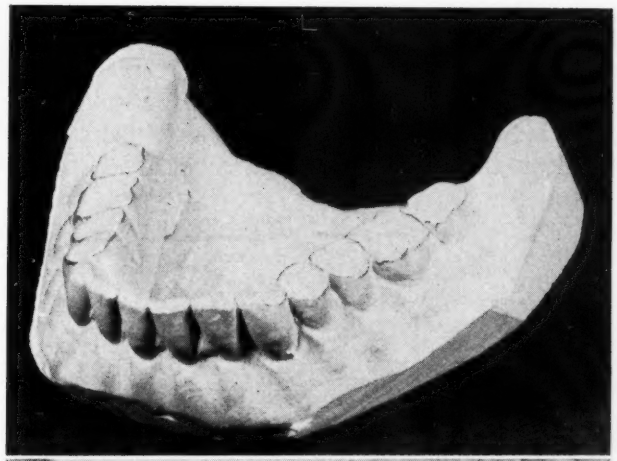
*C. H. Moses: Personal communication, Aug. 13, 1956.

†C. H. Moses: Personal communication, March 8, 1954.

When the buccal cusps of the lower teeth and the lingual cusps of the upper teeth, as in a normal dentition, are conformed to the various occlusal movements, the occlusal curve of Spee of youth tends to be reversed, in the bicuspid and first molar areas particularly, toward a reverse curve of occlusion.

Fig. 1.



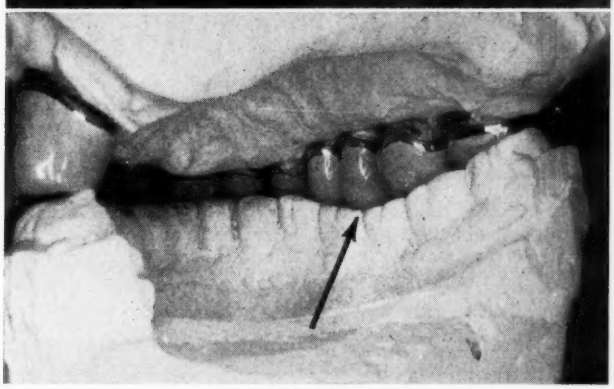


Fig. 2.

Fig. 1.—This occlusal plane or curvature was changed by wear from a curve of Spee to a reverse curve within 5 years.

Fig. 2.—A naturally developed individual occlusal plane or curvature used in occlusal rehabilitation. (Courtesy S. Charles Brecker, New York, N. Y.)

COMPARISON OF CONCEPTS

The mechanical approach to occlusion and the occlusal plane or curvature may be stated as follows: The occlusal surfaces should be balanced to the lateral and protrusive movements in order to distribute the occlusal load in occlusal rehabilitation and to prevent tipping of complete dentures when the teeth are rubbed together.

When the buccal cusps of the upper teeth and the lingual cusps of the lower teeth are conformed to the lateral and protrusive movements on an adjustable articulator, a compensating curve similar to the curve of Spee is developed.

The differences between the mechanical and physiologic approaches to occlusion may be stated as follows: The mechanical concept is concerned primarily with

balancing the occlusion to the lateral and protrusive movements of bruxism on a compensating occlusal plane or curvature after centric occlusion has been established.

In the physiologic concept, the objective is to preserve the health of the tooth-supporting tissues by establishing centric occlusion physiologically on an individual occlusal plane or curvature that is in harmony with the functional and bruximatic occlusal movements. Premature contacts are then eliminated from the vertical and horizontal occlusal paths that lead to centric occlusion.

In complete denture practice, the compensating curve of occlusion and the reverse curve of occlusion seem to produce satisfactory results from a strictly occlusal point of view. However, to preserve the health of the supporting tissues by minimizing the shifting of the denture bases, the individual occlusal curvature should be used.

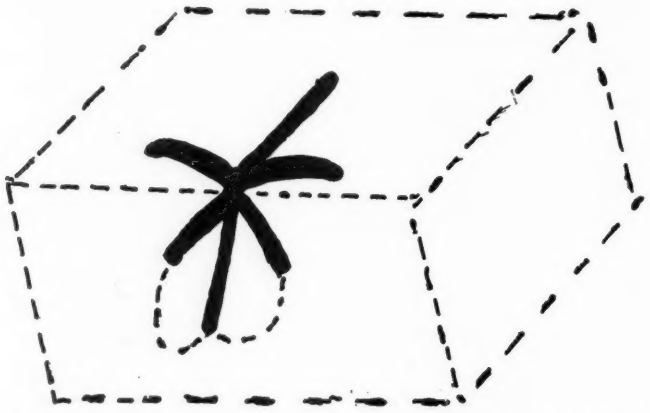


Fig. 3.—Schematic drawing of the path of a tracing point while the six basic occlusal movements are made. Note the paths of the horizontal, lateral, and protrusive movements of bruxism, as well as the paths of the vertical masticating cycles and the swallowing closure.

In occlusal rehabilitation, the compensating curve also seems to produce satisfactory results from the occlusal viewpoint. However, if the supporting tissues are to be protected from traumatic occlusion, the individual occlusal curvature should be used.

In youth, there seems to be a high tolerance of the tooth-supporting tissues to withstand unfavorable occlusal stresses. However, as patients grow older and the tooth-supporting tissues continue to remain healthy, we should be aware that the occlusal curvature has been changed to conform to the chewing and rubbing occlusal movements and that these occlusal adjustments have gradually altered the curve of Spee of youth toward a more favorable individual occlusal curvature.

When the compensating curve or curve of Spee is not adjusted to conform to the vertical and horizontal occlusal movements, the average patient will manifest evidences of pathologic adjustment changes in the tooth-supporting tissues due to the traumatizing effects of the various occlusal movements.

OCCLUSAL MOVEMENTS

There are six major occlusal movements (Fig. 3). Three of these are in the functional group, and three are in the nonfunctional or bruxism group. The func-

tional occlusal movements are in a general vertical direction; the bruxism movements are in a general horizontal direction. There are many intermediate movements within the limits of the border movements of both groups. The lateral occlusal movements of bruxism are anterior to centric occlusion. The lateral occlusal movements of the masticating cycles are posterior to centric occlusion, as are the opening and closing movements of the mandible and an articulator.

Adjustable articulators are used for simulating the basic bruxism movements, and now there is an instrument (Transograph) for simulating the masticating occlusal movements.

One of the principal vertical functional movements that the occlusal surfaces should be conformed to, after centric occlusion has been established, is the constantly repeated process of swallowing saliva. In this process, the mandible rises from its rest position to centric occlusion about 1,500 times every 24 hours, on an average.

Other functional vertical occlusal movements are the right and left masticating cycles and the closures that occur in swallowing saliva when the head is inclined to one side or the other.

All paths of closure to centric occlusion should be free from premature contacts in order to avoid traumatic occlusion and the pathogenic changes that occur in the supporting tissues of the teeth.

The bruxism group of occlusal movements is made in a general horizontal direction. They are anterior to centric occlusion and are familiarly known as the lateral and protrusive movements. It is within this group that patients rub their teeth together under pressure when they are under stress or are emotionally disturbed. As a rule, patients engage in bruxism between one of the lateral and the protrusive movements to a distance of 1.0 to 2 mm. in the incisor region. There is little evidence to indicate that all such patients use the entire area between the extreme lateral movements for bruxism. All rubbing excursions to and from centric occlusion should be free from premature contacts.

In developing the occlusal plane or curvature and occlusion, both the functional and the nonfunctional groups should be included.

CENTRIC RELATION RECORDS

A physiologic centric relation[2] record at the saliva swallowing terminal is the important key position, and it may be used in the mechanical as well as in the physiologic approaches. This position is not only in harmony with the musculature, the temporomandibular joints, and the occlusal surfaces, but it is the terminal for the functional occlusal movements. In the mouth, this occlusal position is momentary, but it becomes fixed when it is transferred to an articulator.

A physiologic centric relation record is anterior to the retruded hinge closure terminal and is generally anterior to the apex of an arrow-point tracing made with a *lower* central bearing point.

A forced retruded hinge closure to a centric relation position is not acceptable physiologically because it is not only distal to the natural centric relation position, but because it is out of harmony with the musculature and the temporomandibular joints. When patients were induced to close to the extreme retruded hinge terminal,

it was generally observed that the mandible had a tendency to move forward to the more comfortable saliva swallowing terminal. This view has recently been confirmed by Posselt.*

A centric relation position determined by and recorded by a lower central bearing point at the apex of the arrow tracing is also not acceptable physiologically because, generally, it too is distal to the natural saliva swallowing terminal. However, a centric relation position recorded at the swallowing terminal would be acceptable.

A centric occlusion established from a centric relation made with a retruded lower central bearing point record invariably tends to move anteriorly to the natural swallowing terminal.

When a centric occlusion is established to a retruded hinge closure position, or to a centric relation position determined by a retruded lower central bearing point, the patient will close to these newly acquired distal positions as long as he can tolerate the restraint. However, when the patient ultimately relaxes, the mandible tends to move forward to the more comfortable physiologic centric position.

The forward movement of the mandible, from the abnormal retruded positions to the natural swallowing terminal, disrupts the occlusal relationship, causing severe traumatic occlusion during the chewing and rubbing occlusal movements. Such malocclusions produce the very effects we seek to avoid, namely, the destruction of the tooth-supporting tissues.

The physiologic centric relation, therefore, is the preferred position for all cases ranging from natural teeth to complete dentures, because patients are constantly and naturally moving the mandible to this position in swallowing saliva throughout the day.

CHANGES IN THE OCCLUSAL CURVATURE

In the mouth, the vertical masticating movements tend to change the curve of Spee toward a reverse curve by conforming the buccal slopes of the lower buccal cusps and the lingual slopes of the upper lingual cusps of the bicuspids and first molars, particularly. This effect may be readily observed in the mouths of middle-aged people with complete natural dentitions and healthy supporting tissues. It may also be observed in complete dentures with soft plastic teeth that have been in use for several years. The supporting tissues generally remain healthy. Function rather than time is the factor in changing the occlusal planes or curvatures. Many Eskimos have their occlusal curvatures changed from the curve of Spee to reverse curves by the time they are 20 years old. By conforming the occlusal curvatures to the functional movements, the health of the supporting tissues tends to be preserved.

Users of coarse foods which require strenuous and prolonged chewing invariably have their original occlusal curves of Spee changed toward reverse curves. The incidence of caries is usually low, and the tooth-supporting tissues are generally in healthy condition in these patients.[3]

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*Ulf Posselt, Lecture before the Greater New York Academy of Prosthodontics, New York, N. Y., April 3, 1956.

Users of modern refined foods, which require little and light chewing, generally retain their original occlusal curves of Spee or have them only slightly modified as they approach middle age. The incidence of caries is generally high, and the tooth-supporting tissues generally manifest evidences of periodontal involvements.

Failure to conform the occlusal surfaces and the occlusal plane or curvature of natural teeth to the various occlusal movements results in bone loss, tooth mobility, and pocket formations. Failure to conform the occlusal surfaces and the occlusal curvature of complete dentures to the various occusal movements results in the loss of the denture-supporting gum and bone tissues due to the abnormal and excessive movements of the denture bases.

Unfortunately, the American diet does not consist of foods that are sufficiently hard and fibrous to encourage mastication and thus bring about the necessary changes in the occlusal curvatures to conform them to function. Consequently, when the occlusal curvatures or surfaces are not adjusted to the various occlusal movements, it is not uncommon to find pathologic changes taking place in the tooth-supporting tissues due to traumatic occlusion. This situation dentistry earnestly seeks to avoid by instituting such preventive measures as early clinical diagnosis, periodic roentgenographic examinations, and the removal of premature contacts along the paths leading to centric occlusion, and by other means. Early detection and treatment of pathologic changes in the tooth-supporting tissues result in a favorable prognosis.

Philippas[4] points out that the ancient Athenians had occlusal curvatures and surfaces that were changed to reverse curves and that the supporting bone structure remained in good condition. Similar effects may be seen today, but with much less frequency because coarse fibrous foods are seldom served and there is less need for the vigorous and prolonged chewing that is so necessary for a change of tooth surfaces and the protection of the health of the supporting tissues of the teeth.

One of the objectives of modern dentistry is to have the natural teeth last a lifetime by preventing the supporting tissues from being deformed by pathologic adjustments when the occlusal surfaces of natural teeth are not conformed to the rubbing and chewing movements.

The occlusal treatment recommended follows the natural pattern of naturally conformed teeth. In order to accomplish this, all the paths leading to centric occlusion are cleared of premature contacts by adjusting the buccal slopes of the lower buccal cusps and the lingual slopes of the upper lingual cusps as may be indicated by tests. The tests involve placing 30-gauge casting wax over the occlusal surfaces of the teeth instead of using carbon paper to locate the premature contacts (Fig. 4).

INDIVIDUAL OCCLUSAL CURVATURES

In occlusal rehabilitation, the asymmetric occlusal surface curvature that the patient has developed normally up to the time of rehabilitation (Fig. 5) is used instead of reverting to the occlusal surface curvature of youth or a flat plane.

When the occlusal curvature is partially edentulous, or when it is obvious that it is badly deformed and not suitable for use with the basic occlusal movements,

then an individual occlusal surface curvature should be developed. This surface should be in harmony with the vertical as well as the horizontal occlusal movements. This may be accomplished by bridging the void or building up the deformed area with an acrylic resin splint and then conforming the occluding surfaces to the various occlusal movements.

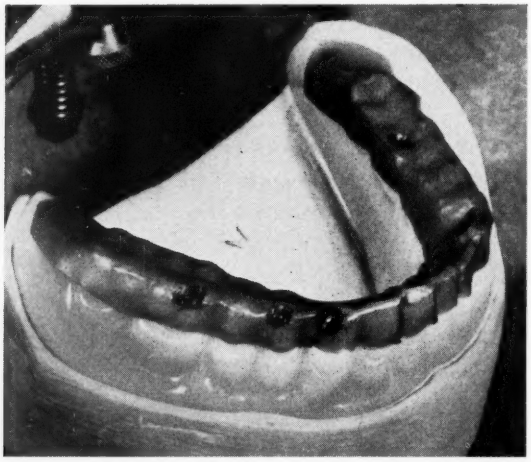

Fig. 4.—Casting wax (30 gauge) is used instead of articulating paper to locate the premature contacts. (From Shanahan, Thomas E. J.: Physiologic Jaw Relations and Occlusion of Complete Dentures, J. Pros. Den. 5:319, 1955.)

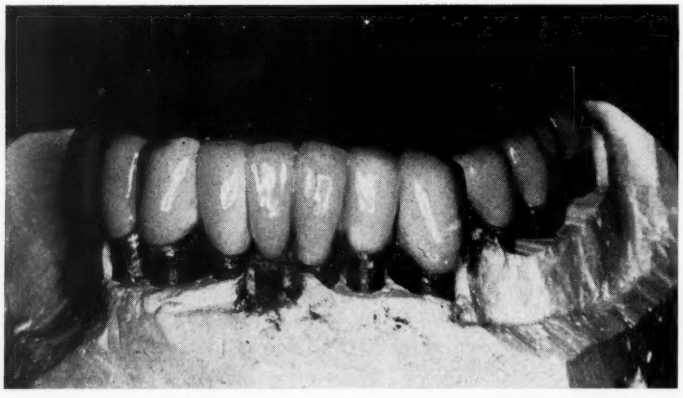

Fig. 5.—A lower individual occlusal plane or curvature used in occlusal rehabilitation. (Courtesy Alexander Leff, Brooklyn, N. Y.)

In complete dentures, it is just as important to develop an individual occlusal surface curvature as it is to make individual impressions. Stock predetermined occlusal curvatures are not acceptable physiologically because they are not in harmony with the musculature, the temporomandibular joints, or the various occlusal movements.

One of the simplest means for developing an individual occlusal plane or curvature for complete dentures that is in harmony with the occlusal movements is as

follows: After the physiologic vertical dimension has been established with occlusion rims in the usual manner, the occlusion rims are luted together in the mouth in physiologic centric relation. The casts are then clamped on a Galetti articulator without stone or plaster.

With the centric relation and the vertical dimension fixed, the arbitrary occlusion rims are made to conform to the various occlusal movements. The occlusion rims are lubricated and warmed slightly in water, then inserted in the mouth, and the patient is instructed to rub the occluding surfaces together lightly. Then the patient is asked to chatter the occluding surfaces together, to chew lightly on each side, and to swallow. This is the first step in establishing an occlusal plane that is in harmony with the various vertical and horizontal occlusal movements. The occlusion rims are then returned to the articulator.

If a space appears between the occlusion rims in the molar region on one or both sides, the height of the upper rim is reduced in that area and the lower occlusion rim is built up to occlude with it. The occlusion rims are lubricated and warmed slightly, and the horizontal rubbing and the vertical light chewing movements are continued until an occlusal plane or curvature is developed that is in harmony with the various occlusal movements and without a space between the occlusion rims when they are returned to the articulator. The occlusion rims are clamped together in centric relation, the casts are removed from the instrument, and the entire assembly is sent into the laboratory.

LABORATORY TECHNIQUE FOR COMPLETE DENTURES

The dental technician now has a pattern prescribed for setting up teeth to the individual asymmetric occlusal plane or curvature. In the laboratory, the dental technician mounts the casts on an articulator (Fig. 6). A separate occlusion rim is used for the face-bow mounting.

In order that a hard surface is available to set the teeth against, a counter of the lower occlusal plane or curvature is made and attached to the upper occlusion rim. This is accomplished by reducing the height of the upper rim 2 mm. and filling in this space with stone (Fig. 7).

The lower teeth are then set up to the counter of the lower occlusal plane or curvature (Fig. 8). The upper teeth are occluded with the lower teeth in the usual manner. The entire set-up is then completed and made ready for the try-in and processed.

BRUXISM TESTS

After the dentures have been in use for several days, the occlusion is tested for premature contacts during the lateral and protrusive rubbing movements. This is accomplished by placing strips of 30-gauge casting wax over the occlusal surfaces of the lower teeth and then asking the patient to rub his teeth together for several minutes. If an incisal edge or a buccal cusp appears through the wax, it indicates the location of a premature contact (Fig. 4). The area is marked and reduced with a suitable stone. If a lingual cusp shows through the wax, it indicates the presence of a premature contact on a lingual cusp of an upper tooth. To locate

this prematurity, the wax is removed from the lower denture and strips of casting wax are placed over the occlusal surfaces of the upper teeth. Then the patient is requested to repeat the rubbing movements. When the premature contact is located on the upper lingual cusp, it is marked and reduced.

Fig. 6.

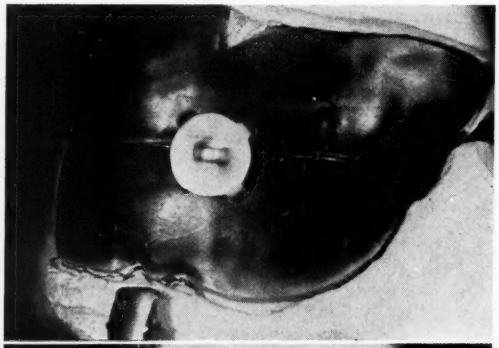

Fig. 7.

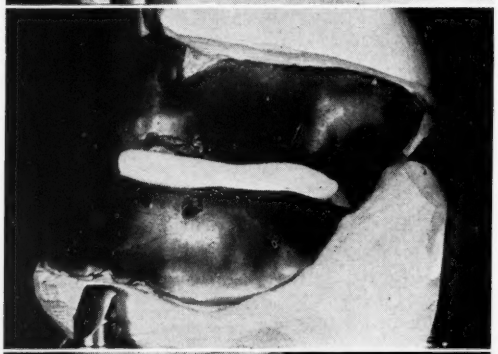

Fig. 8.

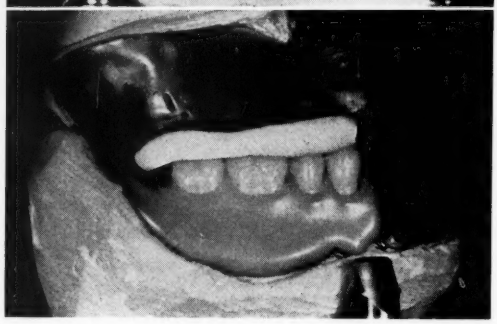

Fig. 6.—The individual occlusal plane which is furnished to the dental technician as a prescription for setting the teeth.

Fig. 7.—A stone counter attached to the upper occlusion rim is poured against the lower occlusal plane or curvature.

Fig. 8.—The lower teeth are set up against the counter of the lower occlusal plane.

The reason for adjusting the buccal slopes of the lower buccal cusps and the lingual slopes of the upper lingual cusps is that we are following nature's plan of adjusting teeth for the preservation of the health of the tooth-supporting tissues, in keeping with the physiologic approach to occlusion and the occlusal plane or curvature.

FOOD CHEWING TESTS

Finally, the dentures are submitted to the test of actually chewing food in order to detect and locate any premature contacts and to learn more about the relationship of the upper and lower teeth during the actual process of masticating food. In a method suggested by Skinner,* a thin wax covering is placed over the upper or lower teeth, and the patient is given bread, cake, or banana to chew on in order to evaluate the functioning versus the nonfunctioning side. According to Skinner, this method provides the key as to how to adjust the occlusion for the improvement of the stability of both dentures.

The method I use consists of placing strips of 30-gauge casting wax over the occlusal surfaces of the lower teeth as previously described. The patient is given a piece of fresh crustless bread, about one-half inch square, with instructions to chew on one side only (Fig. 9). After the portion of bread is swallowed, the lower denture is removed and the wax covering the occlusal surfaces is carefully examined for exposed cusps. If the wax over an exposed cusp is obviously *worn* through, it indicates that the cusp has been in premature contact with the upper tooth during mastication. This is a definite traumatic functional contact that must be reduced because it will cause the denture bases to shift and traumatize the supporting tissues.

Fig. 9.—The masticating tests. The lower teeth are covered with 30-gauge casting wax and the patient is given a small piece of bread with instructions to chew on one side only. The wax is inspected to determine the location of premature contacts during mastication.

If the wax is obviously *torn away* from the cusps, it indicates that excessive pressure was exerted during mastication and that smaller pieces of bread should be used for the test. If the indentations in the wax are slight, it indicates that insufficient pressure was used during mastication and that larger portions of bread should be used. The average force required to masticate fresh crustless bread is estimated to be about one pound.[5]

*C. N. Skinner: Personal communication, May 17, 1957.

The opposite side is tested and adjusted in a similar manner. When the tests are completed, a very thin transparent film of wax generally remains over the occluding surfaces of the lower teeth.

The introduction of food between the occlusal surfaces, one of which is covered with wax, is a much more realistic and valuable method of testing for premature contacts than having the patient go through the motions of chewing with only wax interposed between the occluding surfaces.

The purpose of testing with food is to locate and remove any premature contact that may cause the denture bases to shift and traumatize the denture-supporting tissues during mastication. It is suggested that these simple tests be extended to include all forms of occlusal restorations and replacements for the protection of the health of the supporting tissues of natural and artificial teeth.

The above tests are applicable to normal arrangements of natural teeth, occlusal rehabilitation, and denture teeth; deviations, such as cross-bites, deep vertical overlaps, arches with missing teeth, and periodontal involvements, should not be included in these tests because treatments for such conditions require variations of the technique.

CONCLUSIONS

In advocating the use of the individual occlusal plane or curvature and occlusal surfaces conformed to both the rubbing and chewing movements for occlusal rehabilitation and complete dentures, I believe that the patients will be more comfortable, that the restorations and replacements will have a longer and more useful life, and that the supporting tissues will tend to remain healthy as long as they are free from the effects of traumatic occlusion.

Adjusting the occlusal surfaces of natural teeth and complete dentures to the functional and nonfunctional occlusal movements on individual occlusal planes or curvatures is preferable to having the supporting tissues pathologically adjusted and deformed by the forces of traumatic occlusion.

REFERENCES

1. Pleasure, M. A.: Readers' Round Table, J. Pros. Den. **6**:577, 1956.
2. Shanahan, T. E. J.: Physiologic Vertical Dimension and Centric Relation, J. Pros. Den. **6**:741, 1956.
3. Klatsky, M., and Fisher, R. L.: The Human Masticatory Apparatus: An Introduction to Dental Anthropology, Brooklyn, 1953, Dental Items of Interest Publishing Co., Inc., Chapter VI.
4. Philippas, G. G.: Effects of Function on Healthy Teeth: The Evidence of Ancient Athenian Remains, J.A.D.A. **45**:443-453, 1952.
5. Yurkstas, A., and Curby, W. A.: Force Analysis of Prosthetic Appliances During Function, J. Pros. Den. **3**:82-87, 1953.

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COMPLETE DENTURE PROCEDURES IN CLASS II RELATIONS

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PATIENTS WITH AN ORTHOGNATHIC ridge relation or a severely underdeveloped mandible have been treated by a compromise set-up of the teeth. In this procedure, the maxillary anterior teeth are set as far under the ridge as necessary, and the lower anterior teeth are set as far labially to the mandibular ridge as good judgment will permit. This is done to make the anterior teeth meet ideally. Complete dentures of this type result in marked disfigurement of the patient. The lips sink in, the profile suffers, the contour of the face is marred, mastication is poor, speech is faulty, and the dentures are uncomfortable. The disfigurement is often so severe that the patient goes into seclusion or resorts to padding the vestibules with cotton. These results are discouraging when the complete dentures have been constructed in centric relation, i.e., with the condyles in their most retruded positions in the glenoid fossae.

A study was made of the natural teeth of patients with orthognathic ridge relations. These patients believed that their dental condition was normal. The majority of these patients had well-formed dental arches with a normal arrangement of teeth in both jaws. The occlusion was good in the patient's own natural median occlusal position. This mandibular position is protruded forward from the centric position. The condyles are anterior to their most retruded positions in the glenoid fossae. In the closing movements the muscles pull the mandible forward as well as up, and the condyles move anterior to their most retruded positions. This is necessary for the teeth to meet in occlusion at the median occlusal position. The patient can be instructed to close, and he will quickly and without effort close the teeth into his natural median occlusal position. This automatic action is a motor pattern executed with facility because of neuromuscular training or constant repetition occurring during mastication. This neuromuscular pattern makes it difficult for these patients to register centric relation. This accounts for some failures to recognize the true ridge relations of these patients during the pre-extraction examination. After the natural teeth have been removed, the memory of the neuromuscular pattern for closing in the natural median occlusal position fades. It is impossible to bring back the effect of this psychic experience in an attempt to re-experience it in memory. In order to preserve this neuromuscular pattern in the patient's memory and to construct complete dentures duplicating the natural median occlusal position, the orthognathic ridge relation with underdevelopment of the mandible must be recognized *before* the natural teeth are extracted.

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TECHNIQUE OF TREATMENT

After pre-extraction records for a patient with this condition are made, the unusual aspects of the case and the prognosis are explained to the patient. Then arrangements are made for the extraction of the teeth. Unless multiple extractions are contraindicated, the remaining posterior mandibular teeth are removed at one patient visit. The remaining posterior maxillary teeth are removed one week later. The ridges are allowed to heal for approximately one month or until the posterior ridges are relatively smooth. The anterior teeth are retained to preserve the memory of the neuromuscular pattern of the natural median occlusal position. When the posterior ridges are healed satisfactorily, the usual immediate denture technique is followed with the exception that the patient's own natural median occlusal position is registered instead of recording the centric relation.

When the anterior teeth are extracted and the immediate dentures are inserted, the patient will automatically close into his natural median occlusal position. The dentures will exhibit perfect stability and retention, cause no discomfort, enable the patient to masticate efficiently, and the appearance of the patient will not be changed. After the dentures are inserted, the patient is instructed to leave the dentures in the mouth for twenty-four hours and to return then for examination.

The follow-up treatment is more complicated than with the usual immediate denture procedures because the memory of the neuromuscular pattern must not be allowed to fade. The dentures should be worn continually except for cleaning, repairs, or refitting. When repairs or refitting of the dentures are necessary, they should be completed within twenty-four hours. The slight fading of the memory of the neuromuscular pattern is quickly re-established after this amount of time. However, if the dentures are left out of the mouth for several days, the fading of the memory of the neuromuscular pattern may be so severe that it is difficult to re-establish.

SUMMARY

A complete denture procedure for patients whose natural teeth are present in an orthognathic ridge relation has been described. The procedure depends upon the immediate denture technique as a means of registering and preserving the neuromuscular pattern in memory of the patient's own natural median occlusal position. The dentures are constructed in this position rather than in the centric position.

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TRENDS IN CLINICAL METHODS OF ESTABLISHING AN IDEAL INTERARCH RELATIONSHIP

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IT IS GENERALLY AGREED that one of the most important, yet elusive, steps in complete denture construction is the correct establishment of vertical dimension and centric relation. Perhaps the reason for this is that there is no exact scientific nor absolutely reliable technique available for the determination of either of these two values. In their proper determination, as perhaps in no other phase of denture construction, is called into play all the skill, knowledge, and judgment that the dentist possesses. The reason behind this is that the effects of improperly established interarch relationships are so far-reaching in determining ultimate denture success or failure.

OPINIONS ON IMPORTANCE OF CORRECT VERTICAL DIMENSION AND CENTRIC RELATION

Young[1] has estimated that failure to establish a correct centric relation is the cause of much discomfort and malfunction in dentures. When using anatomic tooth forms, he feels that an improper centric relation is a fault of about 90 per cent of complete dentures. Further, the deleterious influence of a poor vertical dimension on esthetics is also pointed out by Young. Each patient has his own specific vertical dimension value which is as necessary to reproduce for esthetic purposes as it is to functional and positional relationships of the mandible. Young wrote, "Incorrect vertical dimension may so detrimentally modify facial and mouth physical values that esthetic appearance is totally lost."[2]

Robinson[3] declares that "among the many concepts in denture construction which have been accepted by the profession, the concept of the centric position stands out as the vaguest and most ambiguous, although certainly one of the most important."

McKevitt[4] points out that a 2½ million dollar business in denture adhesive powders has developed in this country because uniform success in denture construction has not been achieved. Thousands of dentures are constructed annually that require adhesives in which the vertical dimension was not properly secured. He said, "Recording centric occlusion is one of the most exacting tasks in denture

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construction. It is a step in which the most inaccuracies occur and contribute to denture failures. Its importance is not appreciated by dentists in general as it should be." He concludes that measurement of vertical dimension and recapturing it within millimeter accuracy may be the key to our problem.

The existing vertical dimension may be lost by the omission of pre-extraction casts, by lengthening its dimension for cosmetic effects, by relining, rebasing, or being totally oblivious to its existence. At the same time, one must bear in mind that a correct interarch relationship may be established by a careful operator, only to have it lost during the processing stage. Shrinkage of materials occurring within the mold during processing must be expected. A shrinkage of up to 7 per cent is possible during polymerization of ordinary acrylic resins. Methods to overcome this problem have been developed and should be employed by the profession in order to eliminate an important source of error.

EFFECTS OF PLUS AND MINUS VERTICAL DIMENSIONS

Silverman[5] points out that if vertical dimension is increased (even 1 mm.) above that found to be normal for the patient, he may experience difficulties in speech and mastication, and the dentures will feel uncomfortable.

Pyott and Schaeffer[6] state that if either too little or too great a free-way space is produced, undesirable symptoms will appear. Classic among these are fractured artificial teeth, midline fractures in the restorations, discomfort and poor retention, loss of alveolar bone associated with flabby ridges, temporomandibular joint pain, sore ridges, and sore tongue.

"Costen's syndrome" has been attributed to an overclosure of the mandible. Here certain ear troubles become manifest together with localized headaches and alleged sinus symptoms. Too great a vertical dimension results in ridge resorption which is nature's method of restoring the altered rest relation of the mandible.

Results of a survey (Tables I to III) bear out these contentions. In answer to the question, "From your experience, what per cent of case difficulties or outright failure would you attribute to a faulty determination of vertical dimension and centric relation?" the replies ranged all the way from 0 to 100 per cent (Table III). The majority of those replying felt that an error in centric relation was the major factor involved in failure. The next largest group said that failure in determining correct vertical dimension was equally as great a contributor to denture failure as was the centric relation determination. A smaller group considered an improper establishment of vertical dimension to be the major cause of denture difficulties.

PRE-EXTRACTION RECORDS AND VERTICAL DIMENSION

In selected cases, a determination of and reproduction of the patient's vertical dimension prior to extraction of the teeth should be made. One such technique utilizing the muscles of speech in active function is described by Silverman.[7] Further aids to restoration of pre-edentulous dimensions in the denture include plaster study casts, photographs, plaster face masks, the Sorenson profile scale,

pre-extraction dowels, the acrylic resin face matrix, and other pre-extraction profile records. Of course the question to be answered is, "Should pre-extraction conditions be restored or duplicated in cases of overclosure?"

TABLE I. CURRENT METHODS EMPLOYED IN DETERMINING VERTICAL DIMENSION AND CENTRIC RELATION

A. *The Question Asked.*—Which method or methods are employed by you in an attempt to arrive at these values?

B. *The Answers.*—

VERTICAL DIMENSION

	Number Replying
1. Patient's tactile muscle sense	56
2. The Willis bite gauge	7
3. Boos' Bimeter	2
4. Scott's precision system	0
5. Cephalometric radiographs	7
6. Phonetics	81
7. Deglutition	60
8. Esthetic appearance	81
9. Pre-extraction plaster casts	36
10. Plaster face masks	1
11. Pre-extraction dowels	2
12. Acrylic resin face matrix	3
13. Facial division into thirds	14

Others suggested included Sorenson's profile scale, the McGee method of facial measurements, parallelism of ridges, visual examination of the free-way space. Many, of course, indicated usage of a combination of the above methods. The most popular combination of methods was numbers 6, 7, and 8.

CENTRIC RELATION

	Number Replying
1. Wax closure with patient pressure evaluation	35
2. Needle point tracing devices not used	13
3. Needle point tracing device used	74
4. a. Type of appliance	
1. Intraoral device used	33
2. Extraoral device used	40
b. Record pattern used	
1. Diamond-shaped recording made	5
2. Gothic arch tracing used	60
3. Arrowhead pattern employed	9
5. Hikock bite check	1
6. Bite plate record with tongue placed at junction of hard and soft palates	18
7. Pressure on the long buccal nerve	0
8. Jaw relaxation aided by manual jiggle from dentist	34
9. Use of acquired centric	4
10. Arbitrary methods	1
11. Pre-extraction plaster casts	10

Others mentioned included the use of the tactile sense of flexation of bilateral temporalis, establishment of rotational centers of condyles, Coble Balancer, Needles-House chew-in technique. Checkbites were made with plaster, modeling compound, wax, and zinc oxide and eugenol.

Schuyler[8] speaks of "bite opening" as an extreme measure, and one which is indicated only in selected cases. His two main reasons are in cases of physical illness resulting from overclosure and in certain cases of esthetic demand. Possible ill results from overclosure may include complex head pains and defective

hearing, impaired masticatory ability, speech defects, and other oral disorders. On the other hand, Schuyler cautions against indiscriminate "bite opening" procedures. He stresses the fact that the health factor must ever be kept foremost in mind and that the dentist must possess more than the usual understanding of the biologic and mechanical factors involved in oral reconstruction.

TABLE II. DIFFICULTY OF ESTABLISHING CORRECT INTERARCH RELATIONS

A. *The Question Asked.*—Has establishment of correct vertical dimension and centric relation been one of the most knotty problems for you to contend with in complete denture construction?

B. *The Answers.*—

	Number Replying
Yes	44
No	56

Several of those answering *no* indicated that it had been a problem for them when less experienced. Some said that centric relation was a problem, while vertical dimension was not. Others said that vertical dimension was a problem, whereas centric relation was not. Quite often when someone said *yes* to this question, he indicated also that he did not use a needle point tracing device in denture construction.

TABLE III. CASE FAILURE AS A RESULT OF IMPROPERLY ESTABLISHED INTERARCH RELATIONS

A. *The Question Asked.*—From your experience, what per cent of case difficulties or outright failure would you attribute to a faulty determination of these values?

B. *The Answers.*—

VERTICAL DIMENSION		CENTRIC RELATION	
Per cent	*Number Reporting*	*Per cent*	*Number Reporting*
0- 9	31	0- 9	29
10- 19	17	10- 19	6
20- 29	17	20- 29	4
30- 39	6	30- 39	7
40- 49	1	40- 49	9
50- 59	9	50- 59	9
60- 69	3	60- 69	3
70- 79	2	70- 79	10
80- 89	3	80- 89	11
90-100	3	90-100	3

Some replying considered vertical dimension to contribute to cause failure to a greater degree than centric relation. Others felt that they contribute equally; some felt that centric relation was a greater cause of failure than vertical dimension. The following data show this compilation.

As A Cause of Failure	*Number Replying*
Vertical dimension	15
Centric relation	43
The same (equal % shown for each)	31

Opinions differed widely on this question as evidenced by the following typical replies.

1. "All failures are complex in nature and cannot be attributed to one phase failure."
2. "If vertical dimension is too great, all cases will fail; if too little, one-third will fail."
3. "The existence of a faulty centric relation, whether of dentist or of patient origin. is the primary reason in my practice for constructing new dentures."
4. "Adequate evaluation is impossible due to changes in supporting area since the dentures were constructed."

Edmand[9] points out that it is readily possible to restore lost vertical dimension through the use of splints and a careful balancing of the occlusion. Correctly taken interocclusal records of the various jaw positions are indispensable in any attempt to balance the occlusion, he feels. He indicates that dentistry is in a position to aid the otolaryngologist in the diagnosis of ear symptoms as a result of improper mandibular positioning and, at the same time, to offer scientific, proved mechanical corrective measures for mandibular repositioning.

IMPORTANCE OF REST POSITION AND FREE-WAY SPACE

Coulouriotes[10] points out that the rest position of the mandible may not remain constant throughout life. He cites the work of Leof[11] who found, by study ing patients over a ten-year period who had developed grinding and clamping habits, that increased tonus in the muscles of mastication subsequently decreased the free-way space. This was because the muscles were ultimately shortened. He feels that when the rest position of the mandible is constant, the levator and depressor muscles are, theoretically, in a coordinate equilibrium, and "rest" is involuntarily assumed after speech or deglutition. When the teeth are out of occlusion and at the rest position, a free-way space exists. During speech, the lower teeth partly traverse the free-way space, while in the act of swallowing, they completely traverse the free-way space. He concludes by saying that most investigators seem to agree that the crux of the problem lies in determining the rest position of the mandible and then allowing the proper amount of free-way space by which the mandible can move into centric occlusion during mastication and deglutition.

Landa[12] stresses the fact that this space is never static. It varies as head position changes, such as when deglutition and respiration (inspiration augments it, expiration reduces it) occur, and during psychologic disturbances such as fear, anxiety, and fatigue. Free-way space is not a simple vertical measurement. An average measurement of 2 to 3 mm. is useful as a starting point in denture construction, but its exact measurement is a matter of *feeling* on the part of the patient, and it is impossible for the dentist to appreciate or appropriate his physiologic sensation of rest or strain. Measurements of 100 subjects provided Landa with an average of 3.07 to 3.67 mm. of free-way space. Extensive fluctuations, plus and minus, from this average were noted, however.

Some investigators feel that, during life, this "space" changes in direct relation to the advanced age of the patient. These conclusions would surely lead us to believe that the maxillomandibular opening cannot be determined by an average applicable to all individuals but must be established on a functional basis for each patient under treatment.

METHODS USED IN ESTABLISHING VERTICAL DIMENSION

Numerous techniques and mechanical devices have been employed in an attempt to establish the ideal interarch relationship. No one method has proved to be complete in and of itself. Arbitrary methods have been used to construct as many successful dentures as has any other mode. Today, men in the profession

are still searching and learning and have concluded that there is still no substitute for experience and common sense.

Leading prosthodontists in the United States today employ esthetic appearance and phonetics more than any other two items in determining a patient's vertical dimension. The employment of deglutition rated third, while use of the patient's tactile muscle sense was close behind. In order of decreasing importance, the following were used: pre-extraction photographs, pre-extraction plaster casts, facial division into thirds, the Willis bite gauge, cephalometric roentgenographs, acrylic resin face matrix, Boos' Bimeter, pre-extraction dowels, and plaster face masks. Other items mentioned as being used by those reporting include Sorenson's Dento-profile scale, the McGee method of facial measurements, parallelism of ridges, and visual examination of free-way space by parting the lips. Many emphasized the necessity of determining physiologic rest position initially, then closing a predetermined or arbitrary amount therefrom.

While much is said about cephalometric roentgenographs, neuromuscular physiology, and electromyography, very likely most dentures result from a simple sequence such as (1) determination of the patient's rest position; (2) subtraction of an arbitrary free-way space from the measurement in no. 1; (3) visual check of the results by employing esthetic appearance, phonetics, and deglutition; and (4) obtaining centric relation by having the patient close "on his back teeth" or close as aided manually by the dentist.

CENTRIC RELATION DETERMINATION

Past and Present Methods.—Although a proper establishment of vertical dimension is difficult in complete denture construction, it would appear that a correct centric relation determination is still a greater problem. This statement is based on the results of a recent survey of 110 leading prosthodontists. All do not agree, however, as evidenced by these two sample statements: "I think that more study is needed in developing correct centric relation rather than in establishing correct vertical dimension." "To me, centric relation is no problem if the Gothic arch tracing is correctly executed and recorded with the Stansbery method of a plaster checkbite."

In the main, our present-day methods of obtaining centric relation are little different from those current in earlier decades. Except for the development of various needle point tracing devices, little that has been developed since has proved to be of lasting value. In 1916, Campbell[13] declared that centric relation was recorded by each dentist according to his favorite method of "getting the bite." In 1933, Gillis[14] felt that some 60 per cent of the dental profession was using the same technique to register centric relation and vertical dimension as was current in 1840. This he termed the "mush bite" technique.

Survey of Present Conditions.—My survey indicates that, although the majority of those reporting did employ needle point tracing devices, a wax record of some sort was used either alone or in combination with checkbites (Table I, part B). In order of decreasing popularity, the following methods of obtaining centric relation were reported: needle point tracing devices; the Gothic arch tracing, used most frequently; and extraoral tracings which were more popular than intra-

oral methods. A small number reported using a combination of extraoral and intraoral tracers. A wax closure with patient pressure evaluation was popular, though not much more so than the method of jaw relaxation aided by manual jiggle from the dentist. A "bite plate" record taken with the tongue placed at the junction of the hard and soft palates was used quite frequently also. Some dentists found pre-extraction plaster casts to be of some value, while fewer numbers used the patient's acquired centric relation, the Hikock bite check, and other arbitrary methods. None reported the use of pressure on the long buccal nerve.

Other aids to a proper centric relation determination included the use of the tactile sense of the bilateral full flexation of the anterior one third of the temporalis muscle, and a record of the hinge relation after the rotational centers of the condyles had been established. The Needles-House chew-in technique was mentioned as was the use of the Coble Balancer.

FUNDAMENTAL CONSIDERATIONS IN CENTRIC RELATION

Kingery[15] declares that each individual exhibits a different horizontal relationship of maxillae to mandible. He points out that we do not establish centric relation, we do not "take" centric relation, we *record* centric relation. In this sense, centric relation might be considered a template to be fitted. In making this record, there are two main requirements to be fulfilled: (1) recording the correct anteroposterior or horizontal relationship of the mandible to the maxillae in a position of centric relation; and (2) equalization of contact on the denture-supporting areas. The latter is most often neglected, according to Kingery. Errors in accurate centric relation determination are either positional or technical.

Kingery feels that there are many methods or techniques, all of which are capable of producing acceptable results. "However, the criteria for final acceptance of their accuracy, I feel, are and always will be dependent upon the honesty, judgment, and intelligent vision of the operator."[16]

POSSIBLE INVESTIGATIONS OF MAXILLOMANDIBULAR RELATIONS

The following question was asked in my survey: "What type of investigation do you feel would yield more quantitative and reliable information on the values needed or methods of execution?" The three most common replies had reference to research in the fields of electromyography, muscle physiology, and cephalometric roentgenographs. Many other suggestions were offered, such as improvement of articulators, research on basic fundamentals, accurate rest position determinations, development of a functional occlusal pattern, and further simplification of present techniques.

Although seven of the 110 replying to the questionnaire reported using cephalometric roentgenographs at the present time, several others commented that they felt this method was too expensive to be of general use to the profession. A similar feeling seemed to exist with respect to the electromyograph.

RESULTS OF PROSTHODONTIC SURVEY

Frequent reference has been made throughout this essay to the results of a recent survey of leading American prosthodontists as conducted by the author.

Some 185 dentists were sent copies of a questionnaire. One hundred and ten replies were received. The questions asked together with the tabulated numerical results where applicable follow. Since some dentists did not answer all of the questions, each table does not show a total of 110 replies.

SUMMARY AND CONCLUSIONS

1. Although it is true that the profession has not come to general agreement on terminology and the method of establishing maxillomandibular relations, much progress has been and is being made which makes for better understanding and technique.

2. Studies by numerous investigators have substantiated the importance of restoring the normal vertical dimension and centric relation in complete denture construction. However, so long as dentistry continues to deal with changeable physiologic tissues and individual variations, it is unlikely that any one standard method of determining these values will ever be employed.

3. A consideration of rest position and its relation to other mandibular positions is represented. Its fundamental importance as a basis of denture construction is stressed, together with possible ill effects resulting from its improper establishment.

4. Common methods used in determining vertical dimension are presented.

5. Current methods of obtaining centric relation are little different today from those employed by dentists in past ages. Use of various needle point tracing devices as a check on the established relation is popular and recommended by the profession at large. Mechanical devices for this purpose have generally fallen into disrepute.

6. Future aids to the profession in establishing proper interarch relations include the electromyograph, cephalometric roentgenographs, and research into muscle physiology. While employed to a limited extent today, future help from these sources will probably be dependent upon their availability to the profession as a whole. Research work into such fields as occlusal equilibration, improvement of anatomic articulators, and even basic fundamentals is indicated as an aid to help solve the problem.

REFERENCES

1. Young, H. A.: Diagnosis of Problems in Complete Denture Prosthesis, J.A.D.A. **39**:191, 1949.
2. Young, H. A.: Denture Esthetics, J. Pros. Den. **6**:751, 1956.
3. Robinson, M. J.: Centric Position, J. Pros. Den. **1**:384, 1951.
4. McKevitt, F.: The Measured Vertical Dimension and Denture Adhesive Powders, J. California D. A. **26**:233-238, 1950.
5. Silverman, M. M.: Vertical Dimension Must Not Be Increased, J. Pros. Den. **2**:190, 1952.
6. Pyott, J. E., and Schaeffer, A.: Centric Relation and Vertical Dimension by Cephalometric Roentgenograms, J. Pros. Den. **4**:35, 1954.
7. Silverman, M. M.: Vertical Dimension Must Not Be Increased, J. Pros. Den. **2**:188, 1952.
8. Schuyler, C. H.: Problems Associated With Opening the Bite Which Would Contraindicate It as a Common Procedure, J.A.D.A. **26**:734, 1939.
9. Edmand, P. A.: Restoring Lost Vertical Dimension, J.A.D.A. **25**:849, 1938.
10. Coulouriotes, A.: Free-way Space, J. Pros. Den. **5**:194, 1955.

11. Leof, M.: Revision of Accepted Dicta on Mandibular Position, New York D. J. **20**:8, 1950.
12. Landa, J. S.: Practical Full Denture Prosthesis, ed. 2, Brooklyn, 1954, Dental Items of Interest Publishing Co., Inc., p. 149.
13. Campbell, D. D.: Some Basic Principles and Methods in the Reproduction of The Mandibular Movements, J. Nat. D. A. **3**:113, 1916.
14. Gillis, R. R.: A Denture Technique Applicable by the Average Dentist, J.A.D.A. **20**:305, 1933.
15. Kingery, R. H.: A Review of Some of the Problems Associated With Centric Relation, J. Pros. Den. **2**:307-319, 1952.
16. Kingery, R. H.: A Review of Some of the Problems Associated With Centric Relation, J. Pros. Den. **2**:307, 1952.

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COMPLETE DENTURE ESTHETICS

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ANY DENTURES WHICH ARE inserted in this modern and scientific era fail to accomplish their goal. They not only fail to restore the dental function, but also the facial appearance and expressions are neglected. All phases in the construction of complete dentures in prosthodontics should be questioned and weighed in order to afford the best possible long-term denture service to the patient.[1]

In the realm of denture esthetics, it would seem that only one aim would be necessary, and that would be to reproduce the anatomic characteristics present before the patient became edentulous. Yet, the dentist must understand the needs and wants of the individual patient and realize that these needs and wants are not uniform, nor do they harmonize with naturalness, age, sex differences, or the fundamentals of esthetics.

Many definitions of esthetics can be found in the literature today. A few of these definitions are as follows:

> "Referring to a product (denture) which has a definite appreciative quality in terms of its material organization of form and color."[2] "Esthetics is the idealizing or harmonizing of the artificial with the natural."[3] "Esthetics is the return to normal vertical dimension."[4] "Esthetics is the science which deduces from nature the rules and principles of facial and dental art."[5]

Young[6] states, "Such definitions are not lacking in decisiveness, yet they may be interpreted as indicating a measure of disagreement as well as unanimity in views. It is apparent that beauty, harmony, naturalness, and individuality are basic major qualities, with perhaps additional minor qualities tending to give that final touch of discord which yields true artistry."

In this modern day, the public has come to realize more and more the value of esthetically functioning dentures. This realization has brought a demand to the profession for more research and further study of the problem.

COMPLETE DENTURE ESTHETICS

The oral cavity should not be considered solely from a standpoint of optimum biochemical function. The mouth as a separate entity lends its personal touch to the personality appearance of the whole individual. By this axiom, the denture base

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as well as the teeth must be considered with equal measure. "The complete denture prosthodontist has more to do with the beauty of a face than any other beauty specialist. The appearance of the entire lower half of the face depends upon the dentures."[7]

Before attempting to achieve the goal of a natural and pleasing expression with complete dentures, it is essential to make a thorough study of the normal facial landmarks. The facial factors to be considered are all significant in producing a pleasing harmonious facial expression. These factors are shown in Fig. 1: (1) the relative over-all size of the face, (2) the proportions of the face and the ratio of the

Fig. 1.—Surface anatomy of the face in relation to complete dentures. *A*, Alaenasi, *B*, naso labial groove, *C*, upper lip, *D*, rima oris, *E*, lower lip, *F*, mentum, *G*, mentolabial groove, *H*, angulus oris, *I*, philtrum, *J*, nostrils, *K*, basis nasi, and *L*, apex nasi.

facial dimensions, (3) the profile of the face, (4) the outline form of the face, (5) the mouth size, commissure length and form, (6) the thickness, form, curvature, prominences, and tenseness of the lips, (7 the creases and folds in the facial tissue, (8) the squinting of the eyes, (9) the breadth of the nostrils, (10) the spatial position of component elements of the face, nose, eyes, mouth, and chin, and (11) facial impress.[8]

The importance of mechanical aids in producing a harmonious facial appearance cannot be emphasized too strongly. Pre-extraction records are highly significant when they can be obtained. These records not only indicate the tooth position, but also the bone structure which forms and supports facial features. Photographs of patients before the loss of the natural dentition will give the dentist an idea of the

goal toward which he can aim. He must take into consideration the age of the patient and any other factors that may have altered the patient's facial expression.

Denture esthetics consists of two elements. These elements are " . . . the teeth and the denture base. . . . the factors relating to the denture base are the reproduction of the contours of the tissue covered by the base, and its staining to reproduce the natural tissue hues."[9]

DENTURE BASE

In the past, denture bases have been constructed of many materials, of which vulcanite was the most satisfactory. Through research, we now have the use of the acrylic resins which lend themselves well to dental use. The main disadvantage of this material is that it has a tendency to shrink upon processing; however, this disadvantage is not appreciable, and the numerous advantages far outweigh this disadvantage. With this material, we are now able to reproduce the natural tissue hues and develop the contours of the tissues to be covered.

Kemnitzer[10] states that patients often choose a smooth, highly polished acrylic resin denture base in preference to a natural-appearing one. This choice seems to stem from preconceived ideas of the patient. Dentures with bases which are not esthetically constructed are more numerous than those with esthetic bases, and so we can understand how these patient ideas are established. Most patients readily can see the advantages of natural-looking denture bases after such advantages have been explained by the dentist. Natural-appearing denture bases should not be considered by a patient outside the mouth since their irregular appearance is far less appealing than when placed in its intended medium.

Most patients can easily adapt themselves to the smooth, highly polished, festooned denture base; however, this type of base will not satisfy the needs and wants of every patient. "The esthetic denture bases are indicated for (1) patients with an active upper lip, (2) patients with a prominent premaxillary process, (3) theatrical performers, singers, and others who may expose normally unobserved gum tissue areas, (4) the psychologic effect on the patient and the dentist."[11]

The flanges of dentures, both buccal and labial, are important in creating facial contours. The flanges can be altered to give a fullness or shallowness to the surface anatomy of the lower half of the face. This alteration should not be carried to the extent that the function of the denture would be impaired since denture function is of primary importance.

The physiologic age of the patient plays a more important role than the chronologic age factor. The tissues to be covered by the denture base have a definite color hue, and these shades undergo physiologic changes in the individual throughout life. The color shade of these tissues can easily be determined and duplicated by comparision with an acrylic resin shade guide. The shades of acrylic resin range from a very pale pink to a strong red and from a light blue to a strong brownish purple. The intended medium of the tooth for esthetic purposes is as important as the tooth itself. We must select the denture base or matrix with as much care and caution as is used in selecting the proper teeth. The denture matrix should interpret the physiologic tissue age of the patient.

Today, with very lifelike material available, we are able to give the denture base a lifelike appearance. We can control the area over the necks of the teeth and, thus, give a gingival tone to the material. By placing vertical fibers on the labial and buccal surfaces, we can simulate vascular appearance and even place these same fibers in a lengthwise fashion in the palate to impart a lifelike look (Fig. 2).

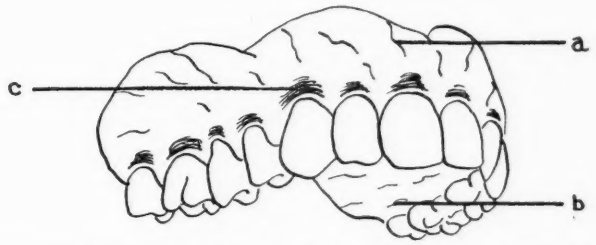

Fig. 2.—Diagrammatic illustration of colored fibers placed in the denture base to simulate a lifelike appearance. *a*, Vertical fibers, *b*, horizontal fibers, *c*, tissue blanching.

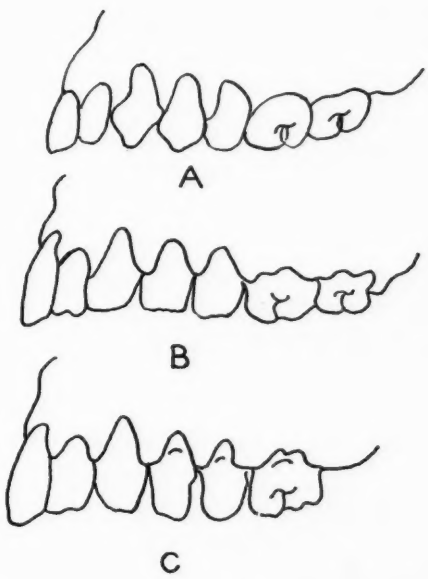

Fig. 3.—Diagrammatic illustration of interdental papillae for denture matrix esthetics. *A*, Youth, *B*, middle age, *C*, advanced age. (Frush and Fisher, J. PROS. DEN. 7:11,1957.)

The dental age of the patient can be indicated through the denture matrix by the gingival papillae. The edentulous oral cavity has no unattached gingivae, and so there is a loss of the stippled appearance of the tissue. The gingival tissue with its papillae can be festooned in the matrix to place the patient in a certain age group. The papillae should be considered in their length and breadth. "Advancing age can be indicated appropriately by shortening of the papillae, and raising the gingival gum line to suggest recession."[12] (Fig. 3.)

We can now see that the physiologic age of the patient can be expressed in the denture base by the use of shades, festooning, and featuring the proper interdental papillae in such a manner as to increase the illusion of reality.

THE TEETH

The factors relating to the teeth for denture esthetics are form, shape, color, and arrangement. The sex factor has been added to these factors and should be considered for a better esthetic value.

There are three basic classifications of tooth forms: square, tapering, and ovoid. These basic tooth forms are fundamental requirements for establishing face and tooth harmony. The tooth form selected for a particular patient, therefore, depends on the face form of the patient in order to obtain a harmonious esthetic expression (Fig. 4).

The dimension of the replacement area should be considered next. This measurement is made from the distal surface of one maxillary canine to the distal surface of the other maxillary canine. The measurements should be made on the labial surface of a well-contoured occlusion rim. The arch form of this measurement gives the dentist the area to be covered by the six maxillary anterior teeth. If the canine eminence is difficult to recognize on the bony process, it will be noted that a line perpendicular to the ridge and along the alae of the nose will usually mark the distal extent of the maxillary cuspid. The length of the tooth to be used is determined by vertical dimension and the behavior of the upper lip.

The shade of the tooth to be selected usually depends upon the chronologic age of the patient. This is used only as a guide, however, and the complexion of the face surrounding the mouth should be considered. If there is too much contrast between these hues it will upset the harmonious blending for a pleasing appearance. The selection of a proper shade is made by using a tooth shade guide which has shades of teeth relating to chronologic ages from adolescence to old age. The selection of the shade should be made under natural lighting conditions, usually near a window.

The sex factor in esthetics has two phases. The first phase is the selection of the teeth, and the second phase is their arrangement. In the female dentition, the six upper anterior teeth have rounded incisal angles, both mesially and distally, presenting a rounded smooth appearance. In the male dentition, the six upper anterior teeth have sharp incisal angles, both mesially and distally, thus presenting more square-appearing teeth. The incorporation of these characteristics into artificial teeth, either by selection or selective grinding, can add to the femininity or masculinity of the patient's appearance.

Tooth arrangement is probably the most important single factor for esthetics. Boucher[13] states, ". . . the teeth must be placed in exactly the same position as the natural teeth which they are to replace. The contour of the lip, the shape of the mouth, and facial expression depend upon the positioning of the teeth and the contour of the base material which supports the lip and the mouth." This can be done when patients present themselves with natural dentitions. However, when it is not possible to have pre-extraction records, the skill of the dentist is taxed. The teeth

must be arranged to give the lip and surrounding structures their natural appearance and support. The anteroposterior position of teeth in relation to the profile view of the patient is important at this time (Fig. 5).

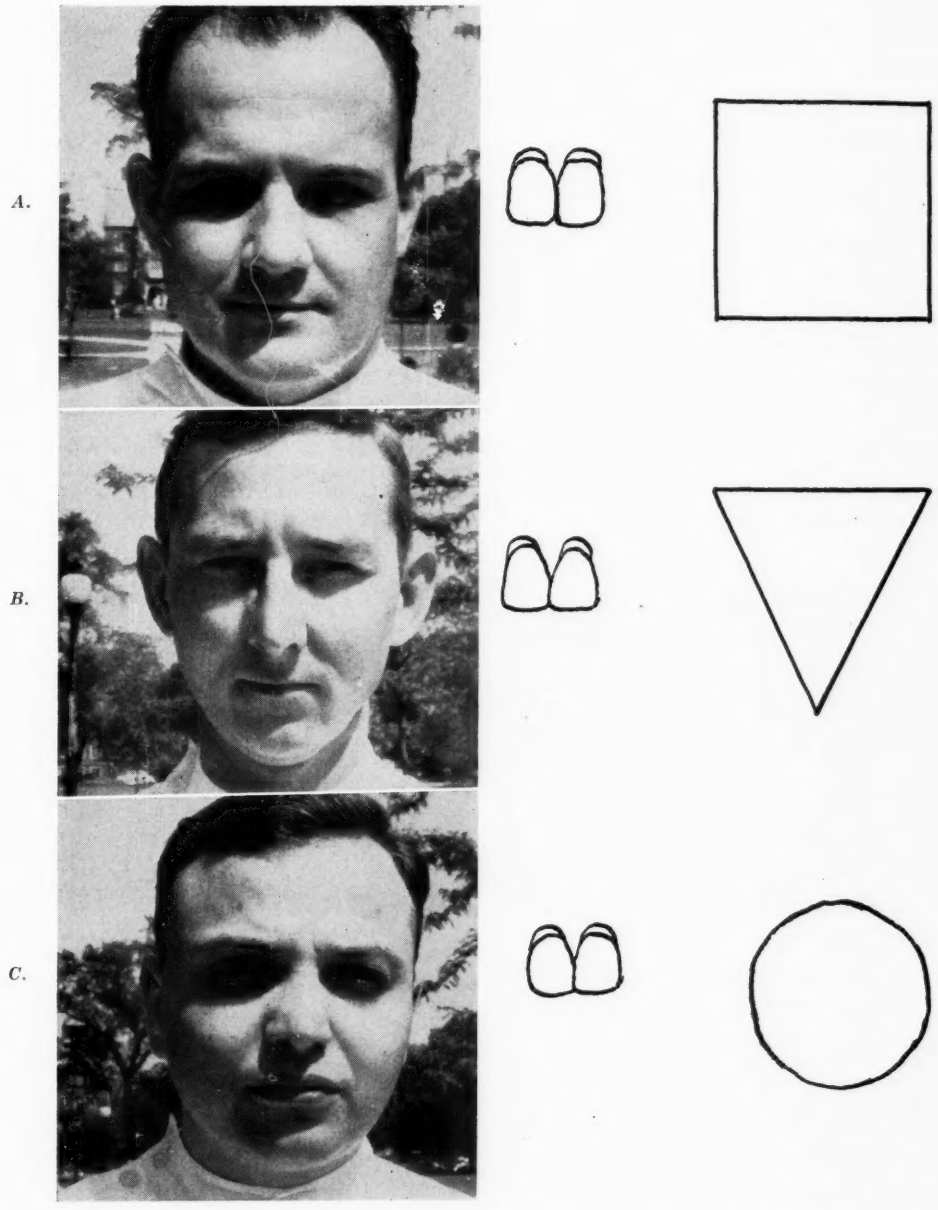

Fig. 4.—Typical types of face forms, *A*, square type, *B*, tapering type, and *C*, ovoid type. It should be noted that a true typical form is quite rare, but rather, a combination of any two types or all three forms may be observed in one face.

Photographs of the patient can be of great assistance in positioning the teeth. A study of the facial contours in these photographs will aid the dentist in arranging the teeth.

The two teeth which chiefly express the sex factor are the lateral incisors and the canines. The mesial surface of the lateral incisor can be positioned slightly labially, or placed to overlap the distal edge of the central incisor. This gives a

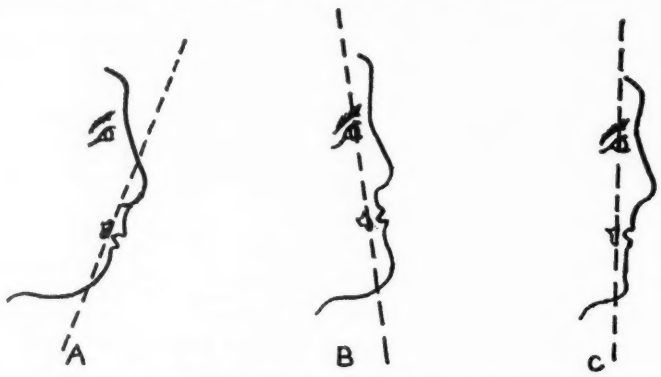

Fig. 5.—Diagrammatic drawing showing the labial face of the central incisor in relation to the profile line of the face. *A*, The cervical end is labial and the incisal edge is lingual to the profile line, *B*, the cervical end is lingual and the incisal edge is labial to the profile line, *C*, both the cervical end and the incisal edge are parallel with the profile line of the face. (Swenson, Merrill G.: Complete Dentures, ed. 2, St. Louis, 1947, The C. V. Mosby Co., p. 197.)

A. *B.*

Fig. 6.—Photographs of a male and female dentition. *A*, A 35-year-old man, *B*, a 22-year-old woman. Note their respective characteristics in relation to the sex factor in dentogenics.

feminine appearance to the dentition. In the male dentition, a straight line arrangement seems to be more characteristic. However, to break up a monotonous straight-line set-up, it is sometimes necessary to tuck the mesial edge of the lateral incisor slightly behind the distal edge of the central incisor, or give the lateral incisor a slight rotation.

The canine region can give a strong robust appearance if the cervical area is positioned labially. This would lend itself well to the patient with an athletic type physique. Conversely, as the physical appearance approaches the feminine, the cervical area of this tooth is placed more lingually, and there becomes a lessening

in the canine eminence. These positions can be varied and combined to best suit the patient's natural physique and expression and yield a harmonious appearance (Fig. 6).

The mandibular anterior teeth are placed according to the surface anatomy which they are to support and to conform to the maxillary anterior teeth. Usually their incisal edge should be positioned on a line parallel with the lower lip.

SUMMARY

This essay has shown esthetics to be a salient factor for successful complete dentures. Although esthetics is arbitrary, it is indispensable for a harmonious facial expression.

For the beginner, it is necessary to recognize these certain basic ideas and attempt to incorporate them into his own techniques for a more satisfying harmony. It is evident from the various definitions of esthetics that each dentist has his own idea of what constitutes esthetics. The dentist must have some primary intentions of what he wants and plans to do before attempting the procedure; however, he should realize the flexibility of esthetics.

This essay is presented by a student for other students so that they may recognize and better understand the basic essentials of complete denture esthetics.

REFERENCES

1. Kemnitzer, Donald F.: Esthetics and the Denture Base, J. Pros. Den. **6**:603, 1956.
2. Glossary of Prosthodontic Terms, J. Pros. Den. **6**:14, 1956.
3. Furnas, I. L.: Esthetics in Full Denture Construction, J.A.D.A. **23**:3, 1936.
4. Brown, H. O.: The Esthetics of Facial Restoration, D. Digest **38**:320, 1932.
5. Lowry, P. C.: Art and Esthetics as Applied to Prosthetics, D. Cosmos **63**:1223, 1921.
6. Young, H. A.: Denture Esthetics, J. Pros. Den. **6**:748, 1956.
7. Swenson, Merrill G.: Complete Dentures, ed. 2, St. Louis, 1947, The C. V. Mosby Co., p. 16.
8. Young, H. A.: Denture Esthetics, J. Pros. Den. **6**:750, 1956.
9. Kemnitzer, Donald F.: Esthetics and the Denture Base, J. Pros. Den. **6**:603, 1956.
10. Kemnitzer, Donald F.: Esthetics and the Denture Base, J. Pros. Den. **6**:603, 1956.
11. Kemnitzer, Donald F.: Esthetics and the Denture Base, J. Pros. Den. **6**:604, 1956.
12. Frush, John P., and Fisher, Roland D.: The Age Factor in Dentogenics, J. Pros. Den. **7**:12, 1957.
13. Boucher, Carl O.: Dental Prosthetics Laboratory Manual, ed. 2, St. Louis, 1950, The C. V. Mosby Co., p. 68.

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THE EFFECT OF HINGE AXIS CLUTCHES ON CONDYLE POSITION

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THE HINGE AXIS IS credited with determining the arc of closure upon which the teeth meet in every contacting position of the mandible. It has also been assumed that pure rotatory movement can occur only in the most retruded position to which the mandible can be carried by the patient's own muscular force. This center of rotation is located with extreme precision in the hinge axis technique.[1]

Electromyographic studies have been reported to show changes in muscle action following slight alterations in occlusion.[2] The present study was undertaken to observe the effect of hinge axis clutches on condyle position.

PROCEDURE

Ten adult patients with natural dentitions, chosen at random, were roentgenographed with the temporomandibular joint technique of Updegrave.[3] Closed and open positions, the latter 35 mm. at the incisor region, were used on both right and left sides. Clutches with studs made for the hinge axis technique were then seated and attached to both upper and lower jaws with alginate impression material. Care was taken to insure comfortable retrusion of the mandible, and roentgenographs were then made of both joints in closed and open positions. Where the 35 mm. block could not be accommodated because of the clutches, the instructions were to "open wide."

OBSERVATIONS

Closed Position.—Eight patients showed translatory movement of both condyles to new positions following insertion of clutches. Four are shown in Figs. 1 to 4. One patient (Fig. 5) showed no obvious change of position of both condyles, with clutches in place. Another showed little change of position of one condyle (Figs. 6 to 7) despite the presence of clutches. The other condyle on this patient, however, did show translatory movement. With these exceptions, all condyles were found to be in closed positions other than those shown without clutches.

Opening Position.—Upon opening incisally 35 mm., all the patients without clutches reached the eminentia. The condyles of eight of the same patients with clutches in place reached the eminentia or went beyond it upon opening. The condyles of two patients, however, failed to reach this location, despite having done so without clutches. One of these patients had one condyle remain in the same

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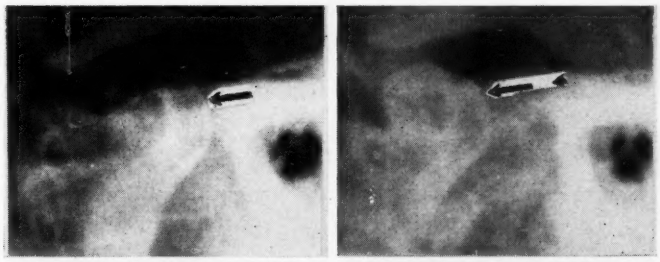
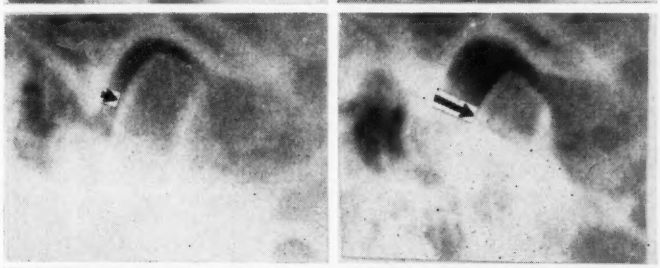


Fig. 1.



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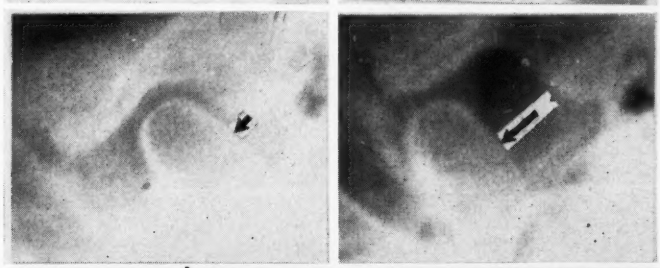

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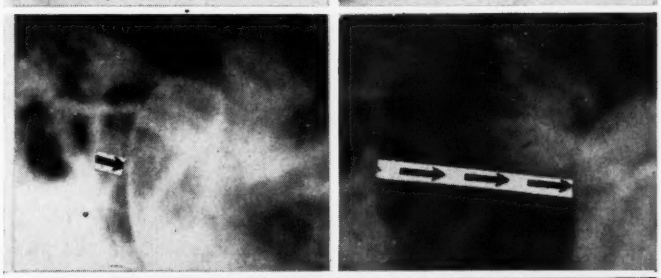

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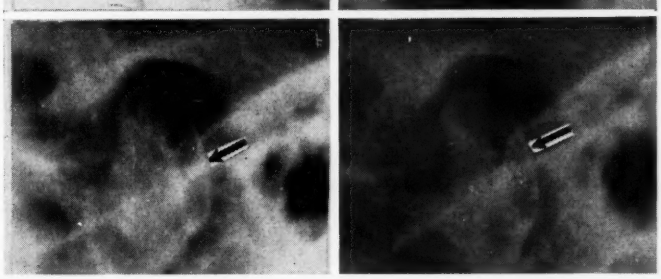

Fig. 5.

Figs. 1-5.—*Left column,* Closed position without cluthes. *Right column,* Closed position with clutches in place.

Fig. 4.—Deep vertical overlap. Note the extreme translatory movement in the closed position with clutches.

Fig. 5.—Cross-bite case showing little, if any, change in position of the condyle with clutches.

position (Fig. 7) upon opening wide, as in closed position, with clutches. This was the only instance of rotatory movement. The condyle of the opposite side did show limited translatory movement (Fig. 8). Another patient showed less translatory movement on opening wide with clutches than on opening 35 mm. without them.

Fig. 6.

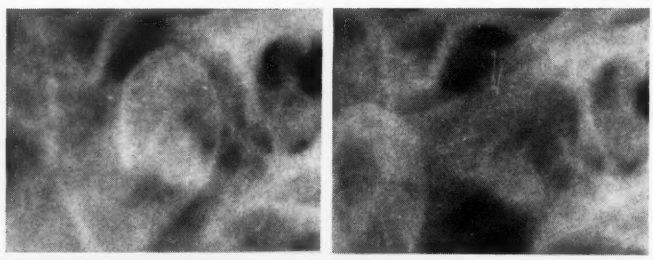

Fig. 7.

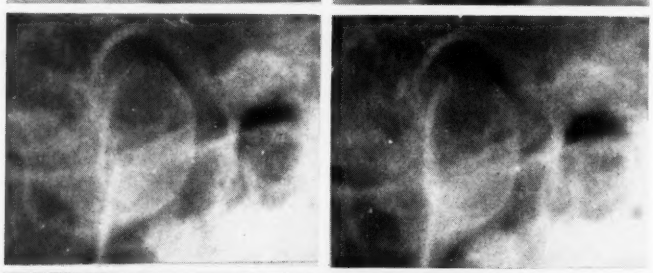

Fig. 8.

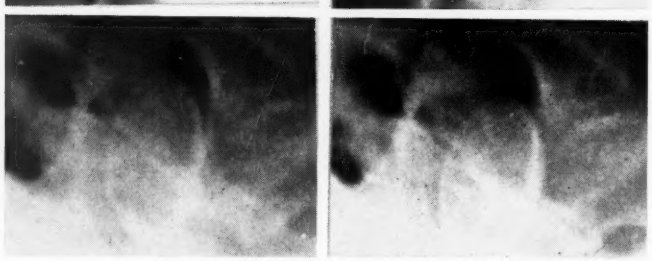

Fig. 6.—Right condyle with the jaws closed and open without clutches.

Fig. 7.—The same patient, the right condyle with the jaws closed and open with clutches in place. Note that there is no translatory movement on opening.

Fig. 8.—The same patient, the left side is closed and open with clutches. Note the limited translatory movement on opening.

DISCUSSION

It appears that the insertion of clutches as used in the hinge axis technique immediately alters the closed position of the condyles in most of the joints studied. Apparently, the presence of clutches can, in some instances, also limit the extent of condylar movement. Hinge axis recordings of presumably functional condylar rotation under such conditions would seem to use an aberrant starting point. There also appears the possibility of abnormal behavior of the condyle upon opening, when clutches are present.

CONCLUSION

A roentgenographic study of condyle positions in ten patients before and after the insertion of hinge axis clutches indicates that alteration of temporomandibular relationships usually occurred when these devices were used.

REFERENCES

1. Granger, Ernest R.: Centric Relation, J. Pros. Den. **2**:160-171, 1952.
2. Moyers, Robert E.: Some Physiologic Considerations of Centric and Other Jaw Relations, J. Pros. Den. **6**:183-194, 1956.
3. Updegrave, William J.: An Improved Roentgenographic Technic for the Temporomandibular Articulation, J.A.D.A. **40**:391-401, 1950.

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ORTHODOXY, COMMON SENSE, AND SCIENTIFIC METHOD

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ORTHODOXY, WHICH IS THE agreement with currently accepted opinions, needs to be challenged. We should never hesitate to test any and all existing beliefs, no matter how well established.

Since an important function of professional societies is to stimulate progress by challenging accepted ideas and testing new ones, let us consider how to go about this. Two important means come to mind. They are common sense and scientific method. What reliance can we place on them?

First, we shall consider common sense. This greatly honored means of arriving at conclusions often turns out to be merely a substitute for inquiry. It is not necessarily good sense. At times, common sense and orthodoxy are difficult to distinguish from each other.

Not so long ago, anyone with common sense could tell that the earth was standing still and that the other heavenly bodies were moving around it. One could actually see the sun and stars rise in the east and set in the west. The sky was "up" and the earth was "down," and anyone with common sense could see that the earth was flat and horizontal.

Such past mistakes of common sense should alert us to the fallacy of blindly accepting current beliefs. We should be especially critical of the so-called self-evident truths.

Individuals who have achieved a certain status in society tend to fight the things that might endanger their standing. They like to be looked up to as authorities and find it more respectable to remain orthodox, often using their prestige to stifle any change. Attaining key positions in organizations, they can and often do suppress the nonconformist.

Let us consider the obstructive power of the extreme conservative who gains a key position. If he is the editor of a scientific journal, he will reject manuscripts that challenge too sharply the current beliefs. If he is the chairman of a program committee, he will guard his organization against clinics and essays that might disturb the general thinking. If he is on the admissions committee, he will keep out the unorthodox applicant for membership. If he is a department head in a university, he will champion popular ideas in order to maintain his prestige and will teach only the "tried and true" methods.

The conformist may not realize that his course is charted largely by the fear of being considered radical. He may be, and often is, a thoroughly delightful fellow

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socially, but he plays it safe and espouses no unpopular ideas. He believes he serves the majority. Of course we need conservatives, but not too great a proportion of them.

Let us consider, on the other hand, the pioneer thinker. He represents a minority. We call him radical. He is often overly insistent on airing his own peculiar views. Whether right or wrong, he annoys us. But we need him.

Both the conservatives and the radicals need to subject what they call common sense to scientific method.

According to most historians, scientific method was practically unknown until about 1600 A.D. when Galileo insisted, much to the scorn of the authorities, that truth lies in testing rather than in textbooks. His experiments are a classic example of the need for challenging orthodox thinking.

Undue regard for authority has delayed progress in many fields. For two thousand years, the great name of Euclid froze the science of geometry until men like Descartes, Gauss, and Riemann did some independent thinking, building, and testing new hypotheses.

In the field of anatomy, we have a good example of the restraining power of the authorities. For more than a thousand years, all questions of human anatomy were settled by reference to Galen. The authorities disdained actual dissection until Vesalius went directly to the human body for the answers.

It seems that no field of human thought is unhampered by orthodoxy and so-called common sense, not even dentistry. In the field of denture service, it was long contended by the authorities that the only rational designs for the chewing surfaces of artificial teeth were precisely those designs that nature took so long to develop. This was just common sense. Common sense also indicated that whatever relations we found in the mandibles of our patients, these were the relations that should be duplicated on the dental articulator for the setting of teeth. Also, common sense said that porcelain was the only suitable material out of which to make artificial teeth. Contending beliefs met with stiff resistance in the beginning. Still striving for general recognition are such radical ideas as occlusal pivots and the manipulation of cranial bones.

Fortunately, new ideas have a way of recurrently intruding themselves on us until we give them attention. A good place to deal with these new ideas is on the programs of our meetings, and much is being accomplished in them. It is heartening to see the open-minded reception accorded new ideas by some members of our prosthetic societies.

These meetings, with their spirit of "give and take," are contributing materially to progress. So long as we can agree that you will challenge me, and I will challenge you, in the true spirit of fact-finding, progress will continue. It is well to remind ourselves that this constant challenging and testing of ideas is a major function of the professional societies.

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PROSTHETIC FUNCTION

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THE THINKING OF THE profession on prosthetic function needs clarification. Too few members of the profession (Group I) are practicing denture prosthesis as a science and following a scientific technique as it should be followed. A much greater number (Group II) are practicing the work as a craft and are dependent on their technicians. The members of still another group (Group III) are trying to practice a scientific technique arbitrarily. The thinking of Group III is irrational to me even though some of them are members of learned prosthetic societies. The members of the profession who are depending on their technicians are following a "rational" procedure because their technicians do not use precise or scientifically designed articulators.

It can hardly be denied that denture prosthesis is a construction job. This being so, engineering principles are applicable to the work, i.e., we have to study, survey, plan, detail, assemble, and complete the job. This does not imply that the individual dentist needs to understand the principles of engineering involved; he is concerned only with a knowledge of how to use in practice the results of these principles. It is true that the members of Group III use engineering terms and are trying to visualize engineering principles for their readers, but because they are doing so arbitrarily, they have no sound foundation present in their minds for the notions occurring to their imaginations. How could it be otherwise? They are dentists, and they assume through their knowledge of anatomy and physiology that they are competent to solve an essentially engineering problem.

The technique followed by those in Group I was given to the profession by an engineer, the late Rudolph Hanau, in collaboration with dental prosthetic specialists. As a general practitioner, I realize what a great contribution Hanau made to the dental profession. While there are other scientific techniques besides Hanau's, it seems to me that his was simplified to make it practical for the general practitioner. Once the dentist in general practice has the knowledge of the Hanau technique, he will find it less exacting work than the skill required to invest a wax pattern for a gold inlay, for instance. It should not be too much to ask of a student that he should be able to make the transfer of the jaw relation and mount the casts on the Hanau instrument, when the only skill required is to be able to mix plaster and soften wax to a desired consistency. There is an erroneous notion, held by the teachers of this work, that the student has to be taught understanding of prosthetic function. Understanding takes years; knowledge can be taught to the undergraduate. Teachers of prosthetics will have to concentrate on the "know how" and let

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the "know why" come when it will. If the "know why" never reaches the mind of the general practitioner, it will make little difference to the patients he serves.

The Hanau technique was not understood by some teachers of this work in the schools. Hanau's book on technique, published in 1930, listed 106 steps. Steps 12 to 32,* inclusive, were omitted by those in authority to teach. These steps were based on the work of Snow and are what make prosthetics a science. When the teaching of this section is restored to the curriculum, it will be found that a much larger percentage of general practitioners will be practicing denture work as a science.

To clarify this thought for those who teach, and to distinguish between denture work as a science and as a craft, let us select three dentists who practice denture work as a science, one in New York, one in Detroit, and the third in Los Angeles. An edentulous patient has his jaw relation transferred and his casts mounted in New York. Assuming multiple casts, he is transported to Detroit and has the transfer made and his casts mounted there; similarly in Los Angeles. It will be found that, in all three places, the position of the casts on the articulator is the same. In other words, when practicing prosthetics as a science, the positioning of the casts was not under the control of the will of the individual dentists or of their technicians. Contrast this with the craftsman method where the procedure is arbitrary whether it is done by the dentists or the technicians.

The thinking of the dentists in Group III is confused. They are arbitrarily using instruments (articulators) designed for a specific purpose. They seem unaware that, in the Hanau instrument, for instance, the engineering principles required to practice prosthetics as a science were incorporated in the instrument by its designer. Hanau[1] stated that "prosthetic function is not primarily a mathematical problem. Measurements of living tissues need only be reasonably accurate to be scientifically acceptable." Teachers of anatomy will agree that anatomic articulations in any part of the body are not mathematically exact. Yet all of these writers in Group III seem to have as their aim mathematical accuracy. It should be apparent that they are working in the dark and can only end in the abyss. Yet they seem to think they are practicing prosthetics as a science. Some state that prosthetics is an arbitrary science.[2] From the fundamental meaning of the two words, one denies the other. Yet they seem content to gloss over this fact. This to me is immature thinking. The cause can be placed in the schools. Those who have the authority to teach prosthetics have not as yet taken a definite stand as to what is and what is not a scientific technique. This, in turn, can be ascribed to a lack of faith that an engineer (Hanau) was able to solve the problem of prosthetic function. His instrument is being used for teaching purposes but it is being used improperly and arbitrarily. The Hanau technique is simple enough for the student to follow if it were being taught as intended.

Lazzari[3] shows three illustrations of correctly mounted casts which are not centered in the articulators. Now, in your mind, place these casts where you think they would look right. You will now have some idea of the amount of distortion that is produced by arbitrary mounting procedures. When it is realized that this

*_Editor's Note._—These steps describe the use of the face-bow and the cast mounting technique.

distortion is confined within the oral cavity, it becomes apparent that this is what makes the difference between a comfortable and an uncomfortable denture.

To carry this thought still further, in comparison with a building operation in the usual sense, the positioning of the casts on the articulator is equivalent to laying the foundation for a building. Suppose a dentist decided to erect a dwelling. He called in a builder, gave him the dimensions of the frontage and depth with instructions to notify him when the foundation was completed. Here is what the dentist found when the foundation was finished. The north and south walls were out of parallel with about eight inches difference in height. Similarly, the east and west walls were out of parallel with about five inches difference in height. The dentist would naturally ask himself what kind of superstructure could be built on a foundation of that kind. Allowing for the difference in the space allotted, our superstructures (dentures) are being built on worse foundations. It is only because of the confined space in which we work that this distortion has not been discernible. The correct positioning of the casts on the articulator is by far the most important part of the technique.

Jamieson[4] writes: "The face-bow is recognized as an important aid in the orientation of casts on an articulator in a position approximating that of the maxillae and mandible to the temporomandibular joint." Until this thought is understood by the teachers of the work, I see no solution to the problem of prosthetic function.

REFERENCES

1. Hanau Engineering Co., Inc.: Intraoral Techniques for Hanau Articulator, Model H, ed. 4, Buffalo, 1930, p. 19.
2. Martone, Alexander L.: The Fallacy of Saving Time at the Chair, J. Pros. Den. **7**:418, 1957.
3. Lazzari, John B.: Application of the Hanau Model "C" Face-bow, J. Pros. Den. **5**:627, 1955.
4. Jamieson, Charles H.: A Modern Concept of Complete Dentures, J. Pros. Den. **6**:587, 1956.

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THE INTERDEPENDENCE OF PERIODONTICS AND REMOVABLE PARTIAL DENTURE PROSTHESIS

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THERE ARE PERHAPS NO TWO dental services more dependent each upon the other than periodontics and removable partial denture prosthesis. In many instances, the concurrent need for both will be critically urgent if more than temporary maintenance of the remaining teeth is to be achieved. Many skillfully executed partial dentures have failed because of inadequate periodontal care of the teeth which remain, just as fine results in periodontal treatment have not succeeded in retaining the teeth in a partially edentulous arch when prosthetic service has not been adequately provided to replace teeth which are missing.

A large proportion of those patients who may require periodontal service will also have one or several missing teeth. In those cases in which tooth migration results, it is futile to expect satisfactory results from periodontal therapy while tooth movement is allowed to continue unchecked. Some of the conditions which predispose to periodontal disturbances (food impactions, impingements due to tipping, traumatic occlusion, etc.) are sure to continue and would, in fact, be likely to become progressively aggravated.

It is almost certain that the partially edentulous condition will continue to increase rather than lessen in the next few decades. The time has been reached when the ultimate effect of the dental neglect of the depression years will become increasingly noticeable. The loss of teeth which resulted from economic pressure in that period and the failure to replace them will by now have produced a very great number of broken dental arches, many of which show periodontal involvement. There are other factors which will increase the need for these combined services. First, many more teeth are being reclaimed today through the effectiveness of modern root canal therapy than formerly. Such salvage, by endodontic means, of critically important teeth in the arch has meant that partial instead of complete dentures can be used in many cases. Second, there has been a marvelous surge of interest in periodontics in recent years. Through the aid of improved methods of periodontal treatment and also better post-treatment care by the patient, the remaining teeth of many patients have been retained, where previously all would have been removed without hesitation. Third, with the advent of multiple tooth preparation under block anesthesia and simultaneous impression registration of all prepared teeth by means of elastic materials, the splinting of weak teeth has been

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greatly facilitated. Without this important means of stress reduction and work distribution, both periodontic and prosthodontic measures would be discouragingly temporary in many cases.

These two important services of modern dentistry will need to be combined and integrated frequently. With this realization of the need, there must be an earnest effort to improve the status of the combined effort by conferences and seminars, where a serious study of mutual problems can be carried out.

CAUSES OF STRESS OVERLOAD IN THE BROKEN DENTAL ARCH

Tooth Migration.—A very large percentage of periodontal patients already will have lost several teeth and, not infrequently, some of those teeth which remain will be considered as not likely to respond to periodontal treatment and will need to be extracted. When the dental arch is thus broken, conditions will result which predispose toward, if not actually cause, lesions of the supporting tissues.

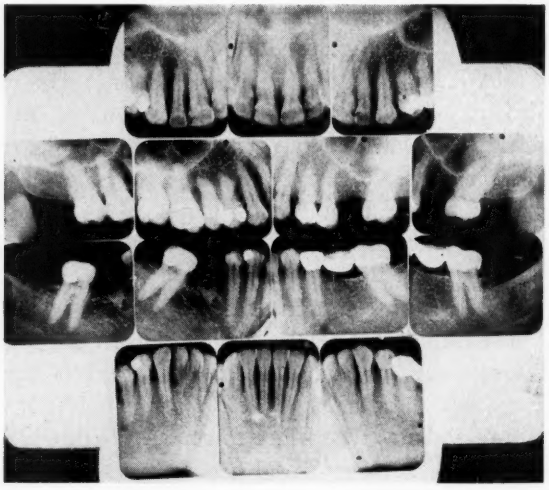

Fig. 1.—In the partially edentulous situation shown on the right, the lower left second molar has tipped mesially into the space formerly occupied by the first molar. If the first molar is replaced soon after its loss, such tooth migration can be prevented (note the replaced right first molar). Frequently there will be resorptive loss of the supporting structures on the mesial side of a tipped molar as is in the left illustration (area of the right lower molar).

The most commonly seen result of the loss of one or more teeth is the drifting of some of those which remain. One form of migration is that a remaining tooth will tilt out of its normal vertical position. This condition is most frequently seen in teeth posterior to an edentulous area (Fig. 1). At least four unfavorable results may be expected to follow, but these will vary in degree and rate of development. First, there will be loss of occlusion so that eventually even the large occlusal surface of the molar may become practically useless from a functional standpoint (Fig. 2). Sometimes the periodontist will be required to make an heroic effort to effect a periodontal recovery of such a tooth, when actually the remaining masticating value is very slight. Second, an unfavorable leverage soon develops. As the tooth

inclines, an area of impingement will occur near the cervical margin of that alveolar wall toward which the tooth leans (Fig. 1). Chronic inflammation caused by this continually repeated traumatization is often followed by formation of a periodontal pocket. Unless such a tooth is supported against further tilting stress (Fig. 3), the periodontal lesion may recur, although it was once eliminated. The usually effective periodontal therapy may not yield satisfactory improvement where tissue tolerance is abnormally low, unless the tooth is *first stabilized*. One of the most important

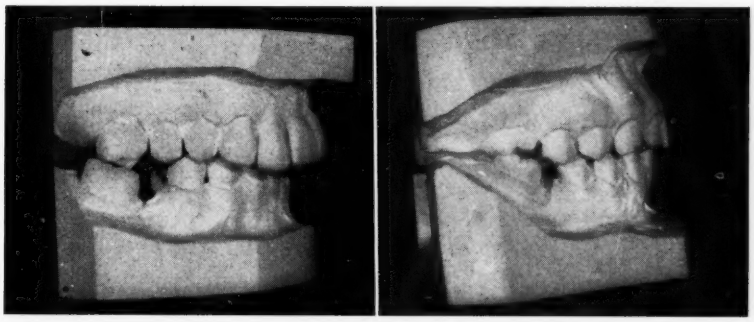

Fig. 2.—Another unfortunate result of failing to replace lost first molars is shown in the severe damage to masticatory functions. Following loss of the first molar, the mesiolingual tipping of the second molar frequently renders that tooth almost useless in chewing.

Fig. 3.—An illustration of the value of replacing a missing first molar even after some migration has occurred. The occlusal relation of the tipped second molar may be restored and, with the placement of a fixed prosthesis (right), further tipping is prevented. The same result can be achieved when a removable appliance is to be used by producing a flat proximal surface (restored second molar seen in the left illustration) instead of the normal convexity of the mesial surface. A similar surface is produced in the contacting area of the removable prosthesis and the second molar can tip no further. Periodontal treatment of such an area will then have a better chance of returning the structures to normal health.

functions of the removable prosthesis then is the prevention of tooth migration, or the reduction of tilting leverage which might have been induced where this type of movement had already occurred. Third, an abnormal relation with its approximating neighbor is produced as the tooth tilts. The adjacent marginal ridges of the two teeth assume unharmonious levels (Fig. 4). This, together with the loss of normal contact relationship, produces food-fiber impaction which is another common etiologic factor in periodontal irritation. Fourth, as teeth in a broken dental

arch assume these new positions, their normal occlusal relations may be disturbed to varying degrees. This becomes more than mere loss of functional efficiency (in itself a serious misfortune) but, as occlusal prematurities arise, trauma of the periodontium is almost certain to follow. According to Ramfjord,[4] "Traumatic occlusion may result, when lip or tongue contact forces a tooth into a position having an occlusal relation which in turn rocks the tooth into another position when functional or bruximatic stress is applied." Such a condition can develop as soon as proximal support has been lost through the removal of one or more teeth from the dental arch. This, then, is one of the most common causative factors of periodontal damage. Its widespread incidence and the difficulty of its elimination makes it a formidable factor in periodontal therapy. The fact that such occlusal trauma might have been avoided by prompt prosthetic replacement of the lost teeth makes its prevalence all the more regrettable. The balancing (or equilibration) of occlusion to relieve periodontal disturbances will be of very temporary benefit unless normal proximal relations are restored so that these teeth are prevented from further migration. Also, as a point in proper treatment sequence, it should be noted that these prosthetic phases should be done prior to the final phases of periodontal therapy.

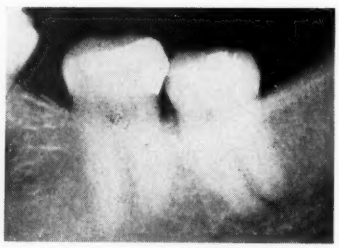

Fig. 4.—Another result of the tipping of a second molar after the loss of the first molar is that the distal marginal ridge of the second molar becomes elevated above that of the adjacent marginal ridge of the third molar. This is conducive to food impaction between these teeth, often leading to periodontal trauma. Even when the contact of these teeth remains reasonably tight, food fibers will be caught against the elevated marginal ridge and driven between them. The resulting periodontal pocket will be accompanied many times by deep caries.

Extrusion.—The results of tooth migration that are most difficult to eradicate are those associated with the growth in an occlusal direction of a nonfunctioning tooth. When occlusal contact is lost, a tooth tends to erupt (Fig. 5) or, in Tylman's[7] terminology, "to egress." Often the bone-forming cells accompany this tooth movement, with the result that the alveolar process also grows in an occlusal direction (Fig. 6). When teeth are to be replaced opposing these extruded teeth, a number of problems are encountered. The extruded tooth or teeth must be shortened to the proper occlusal plane; and then an occlusal anatomy harmonious with the remaining teeth (which may have become quite abraded during years of functional use) must be developed. Obviously, it does not lend to occlusal harmony to have posterior teeth on one side of the arch with high cusps and steep cuspal inclines, while those in another sector are flattened from wear. In the interest of economy, one usually attempts to adjust such teeth by grinding (Fig. 7). However, this process

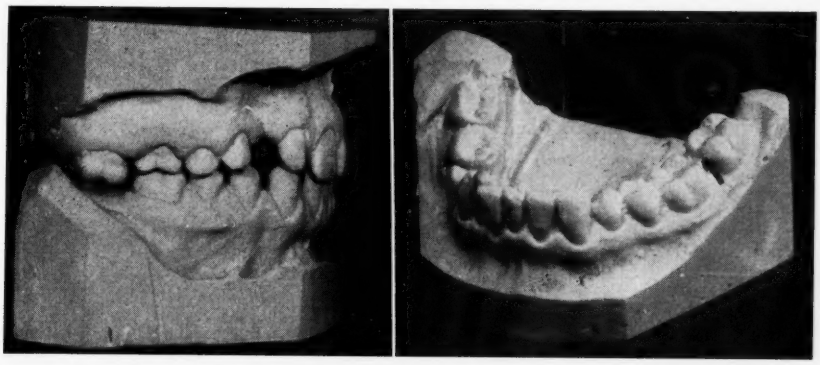

Fig. 5.—Another unfavorable result of unreplaced lost teeth. When taken out of occlusal contact, teeth are almost certain to extrude or "egress" (Tylman). The marginal ridge relationship becomes unharmonious, and food impaction is likely to follow, often with serious periodontal damage.

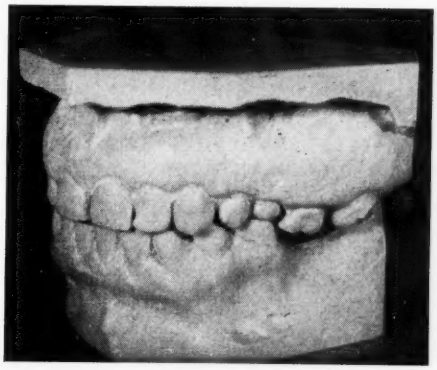

Fig. 6.—An example of the occlusalward growth of the alveolar process as the unsupported maxillary molars move downward. Here the teeth have not really extruded but rather have *grown* occlusally with the alveolar structure following along.

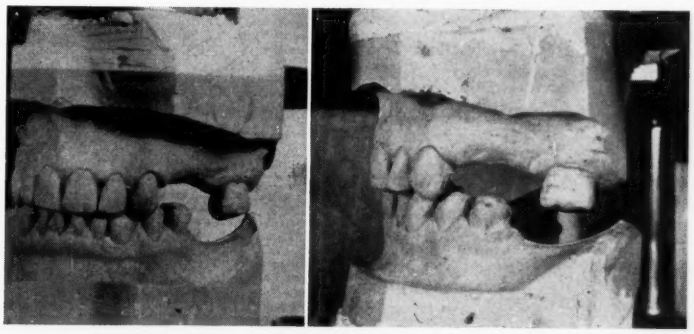

Fig. 7.—The extruded upper second molar and lower second bicuspid (left) have been adjusted by occlusal grinding of the cusps. This has improved the level of the occlusal plane greatly (right) even though it is not yet ideal.

may lead to difficulties: (1) the flattening and broadening of the occlusal surface always tend to produce excessive biting stress loads; (2) there may be difficulty in establishing proper spillways and grooves in the reformed occlusal surface; (3) adequate shortening of the extruded tooth may require the placement of a complete crown, which may, occasionally, necessitate pulp removal; (4) in exceptional cases, extraction of an extruded tooth may be necessary in order to reduce the bone level so there will be vertical space to place any opposing teeth. The alveolar process may have altered to the extent that its level is at about the level of the original occlusal plane. Few patients would allow such extrusion of teeth to continue if they were aware that it was happening, but usually they have not been forewarned about the changes which may follow the loss of a tooth (Fig. 8).

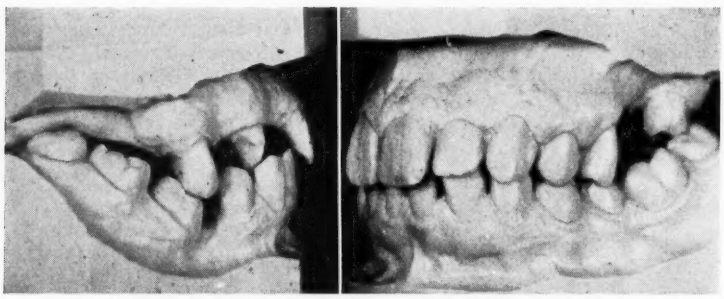

Fig. 8.—Extreme migration of unoccluded teeth accompanied by occlusal growth of the supporting bone and loss of interarch space. It is very unwise to tell a patient that tooth migration may not occur, or that it will happen slowly. Sometimes after extractions, movement of the remaining teeth is rapid and extensive as in the case of these young enlisted men. (Courtesy of Col. Marion Mills, U. S. Army.)

Magnification of Occlusal Stresses.—As the cervical level of the supporting alveolar bone lowers, a serious stress problem develops. The periodontist should be particularly aware of this situation, being alert to detect it early and to give it due consideration. The functional work load which is assumed by each tooth must be adjusted so as not to exceed the tissue tolerance of the structures which are to furnish support. When the intra-alveolar or intraosseous root length is normal (Fig. 9, *left*), the work load is distributed over the maximum area of the wall of the alveolus. Under this condition also, the embedded or resisting part of the tooth is longer than the crown portion and, therefore, has a definite leverage advantage. But, with the loss of alveolar bone, the extra-alveolar or extraosseous segment, that is, from the alveolar crest to the occlusal surface of the tooth, is lengthened (Fig. 9, *right*). When this portion becomes longer than the embedded sector, the leverage disadvantage shifts. Thereafter, the work load is magnified as the lever disadvantage increases. More and more stress is applied to less and less supporting surface.[2] Thus, *in spite of adequate periodontal therapy,* the loss of alveolar bone may continue, simply because the area of support is too little to avoid its traumatization. This is particularly true when the form of the single or fused root is tapered (Fig. 10). Depending on the degree of its taper, the loss of only a small amount of vertical supporting bone may mean much loss in square units of the area of supporting alveolar wall.

While this situation usually concerns only the cervical loss of alveolar bone, it is well to call attention to a similar leverage problem which arises when there is shortening of the abutment root by apical resection. If root shortening, through apicoectomy, should occur when the tooth also has been weakened by cervical bone

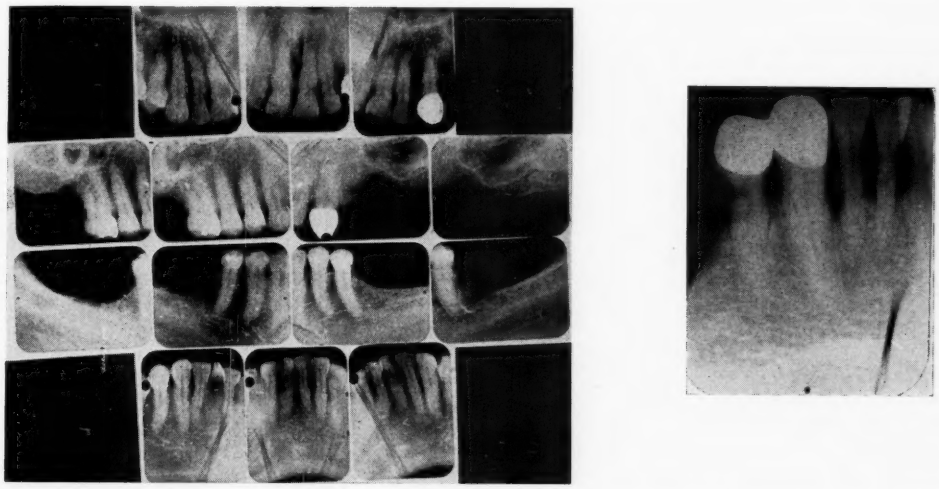

Fig. 9.—Left: The lower right bicuspid teeth show a normal level of supporting bone, while in the same mouth in the lower left second bicuspid area there is bone recession, particularly on the distal side of the tooth. When there has been such bone loss, the units of root surface support are greatly reduced. Overload of the remaining structures which provide support is often the result. Right: Another example of an excessive amount of supporting surface which has been lost because of cervical recession. Here a heroic effort to retain the cuspid and bicuspid has been made by splinting them for abutment use. In this way, the workload will be distributed over a greater area, thus reducing the danger of overload.

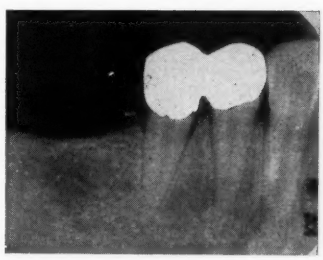

Fig. 10.—If cervical loss of supporting bone occurs, the danger of occlusal overload is much greater when the single root is sharply tapered. The loss of supporting alveolar surface accelerates very rapidly as the bone level recedes down the steep incline of a conical root. Frequently, the roots of a lower second molar will be fused into such conical form.

loss, the tooth becomes questionable as an abutment immediately. The trend toward conservative treatment of apical involvements offers much encouragement to the restorative dentist. Once conditions are made favorable through proper endodontic therapy for the natural recuperative ability of the alveolar process to be fully

released, a remarkedly rapid bone regeneration usually may be seen.[6] Not only may pulpless teeth be rendered sterile and hence capable of being retained safely, but, by accomplishing a regeneration of bone around the root apices of such teeth without resorting to apical resection, they may retain their greatest value as abutments. Having preserved maximum *intraosseous* root length, they will then possess greatest resistance to tilting and twisting stresses to which they would be subjected as partial denture abutments.

When the critically essential cuspid tooth shows involvement of the supporting bone of the apical area, the conservative method of treatment is especially needed. To weaken this last available abutment, when the posterior teeth also are missing, is to create an almost certain necessity for a complete denture service. When root resection can be avoided, it is urgently recommended in view of the possible later need of the tooth as an abutment.

MEASURES FOR PREVENTING STRESS OVERLOADS

Reduction of the Occlusal Table.—When the unfavorable ratio of alveolar support to "clinical crown" length has occurred, immediate steps should be taken to lessen the work load. The most effective approach to this correction is to reduce the size of the contacting occlusal surface of the tooth. In doing this, the *centric occlusal stop* must not be destroyed, else the tooth will extrude more and then again be subjected to the original trauma. Instead, the buccolingual dimension of the mandibular tooth should be reduced to allow more horizontal buccal overlap of the upper posterior teeth. This reduction of masticating surface is not to be viewed with alarm. It would be much better to have less masticating efficiency for a longer time than to have maximum function for only a short period. Actually, the buccolingual narrowing of the contacting occlusal surfaces need not lessen the effectiveness of the masticating apparatus. It does reduce the amount of food which may be engaged in any one masticatory stroke and, therefore, lessens the stress generated during that particular jaw movement. The total masticating result can be achieved, however, by employing more strokes, each being of less force. If the reduction in width of the occlusal surfaces is also accompanied by the deepening of grooves and spillways, there is further decrease of the masticatory stress, as the food bolus is cut rather than being mashed. Too often, dentists have not only failed to heed this need for occlusal surface reduction, but also have used this weakened tooth as an abutment, thus still further increasing the unfavorable overload. Is there wonder that such teeth may have failed?

Splinting of Weak Teeth.—As an additional precautionary measure in the above situation, it is well to splint adjacent teeth by the rigid union of restorations placed in each, with the soldered contact located toward the occlusal level to permit proper stimulation of the gingival tissue beneath (Fig. 11, *left*). Not only is the stress load then divided over more surface units of the wall of the alveolus by gaining a multirooted abutment, but an effective counterleverage also is developed to resist tilting and torque stress loads.

Strengthening an Isolated Second Bicuspid.—The second bicuspid which has an adjacent edentulous area on either side of it is in an exceptionally precarious situation. This premolar frequently will have a single, round, and tapered root. Such

root form is least resistant to twisting forces, and, if its poor form is also coupled to a vertical loss of alveolar bone, there is even less chance of its survival. When this tooth must provide partial denture support (Fig. 11, *right*), it is much better first to place a fixed bridge supplying the missing first bicuspid, thus achieving a union to the stronger cuspid. The resulting counterleverage is especially effective in opposing tilting and twisting forces.

Fig. 11.—Left: The rigid union of adjacent teeth (splinting) offers much hope in preserving teeth weakened by the loss of bone support in the cervical area. This is done preferably by the joining of three-quarter or complete crowns at the area of their contact points. The union should be small in area and sufficiently high to allow proper stimulation of the gingival tissue which lies beneath. Right: Where the second bicuspid tooth stands alone, as in this Class II-mod. I situation, it will be much more likely to succeed as a partial denture abutment if it is united with the cuspid by means of a fixed bridge which replaces the missing first bicuspid.

Avoiding Occlusal Imbalance.—Since most of the forces induced by a removable dental prosthesis must be developed on the occlusal surfaces of the teeth which are replaced, it follows that balanced occlusion is a most important goal for both the periodontist and the prosthodontist. Much of the success achieved by either will depend upon the skill which he manifests in this direction. The total work load must not be increased by any significant amount as the result of malocclusion. It must be conceded that this result is not easy to achieve in the partially edentulous patient, where teeth in various states of malalignment remain to guide and limit both occlusal relations and jaw movements.

The logical starting point toward the goal of balanced occlusion should precede the construction of the removable prosthetic appliance. It is imperative that

all interference to the act of closing the remaining teeth into centric occlusion as the mandible closes to centric relation and all interference to all excursive movements be eliminated as the beginning step in this important part of dental rehabilitation. Most areas of hyperocclusion may be removed by applying basic principles in accepted methods of grinding. However, when restoration of a tooth surface is needed for other reasons, any area of prematurity may be eliminated during its reconstruction.

If a tooth has been moved to and is maintained in a position where it makes a premature occlusal contact, it will slide on a cuspal incline until maximum occlusal contact has been acquired. This slide to centric occlusion may be in a lateral or protrusive direction, and frequently it is a combination of both. As a result, the periodontal membrane is pinched against the wall of the alveolus, producing varying degrees of traumatic injury. Since all of the biting force may concentrate on one such area of prematurity, the damage can be very serious. If identical planes of hypercontact are developed also on the teeth supplied on a free-end, extension type of prosthesis, the tilting force will be greatly magnified by leverage action. Thus, this force may have become many times more destructive in the abutment areas of the supporting tissues. Therefore, the importance of completely eliminating all areas of occlusal hypercontact from the remaining teeth *before* recording centric jaw relation should be apparent.

With the patient able to close directly to centric relation *without sliding,* and capable of free gliding movements with the teeth held lightly in occlusal contact, it becomes the responsibility of the prosthodontist to replace the missing teeth in such relation that this ideal condition is not disturbed. The method of attaining this result is much less important than its routine accomplishment. The author has published his views[1] regarding this step and has detailed a simplified yet dependable method of achieving balanced occlusion with *least postinsertion adjustments* (Fig. 12).

Avoiding an Initial Overload.—Many partial dentures of the free-end extension base type are ruined because an excessive occlusal load is permitted in the early months of their use. Frequently, the posterior teeth may have been removed many years before and not replaced. In this state of reduced use, the alveolar structure will not have been maintained at its maximum of supporting capability. Alveolar bone is particularly prone to show "disuse atrophy" in areas of the dental arch from which function has been eliminated by the extraction of teeth. Sicher[5] has described this type of osteoporosity as "resulting from the normal process of removal and replacement of bone elements which goes on constantly. In an area where functional stimuli have declined, there is no need for maximum replacement, and the bone simply does not reform to its previous pattern." This phenomenon is noted by Glickman[3] in these words, "Alveolar bone is dependent upon functional stimulation for the preservation of its structure." Mouths which exhibit a perfect alveolar bone condition in the rest of the arch frequently show extensive loss of the residual ridge and varying degrees of osteoporosity in an area of disuse. In such cases, it is quite usual to see considerable resorption beneath the tissue-borne base of a partial denture which supports the replaced teeth. This occurs to a much greater degree during the first few months of appliance wear. Until the bone has

been reorganized so as to be capable of supporting the newly applied work, the tissue tolerance is likely to be exceeded and the vertical level of the ridge reduced.

Two things can be done to lessen the extent of this resorptive process. First, the maximum extension of the base borders can be obtained (short of impingement of the moving tissues), and the most equitable distribution of the work load throughout the area of supporting tissue can be achieved. The margins of the denture base

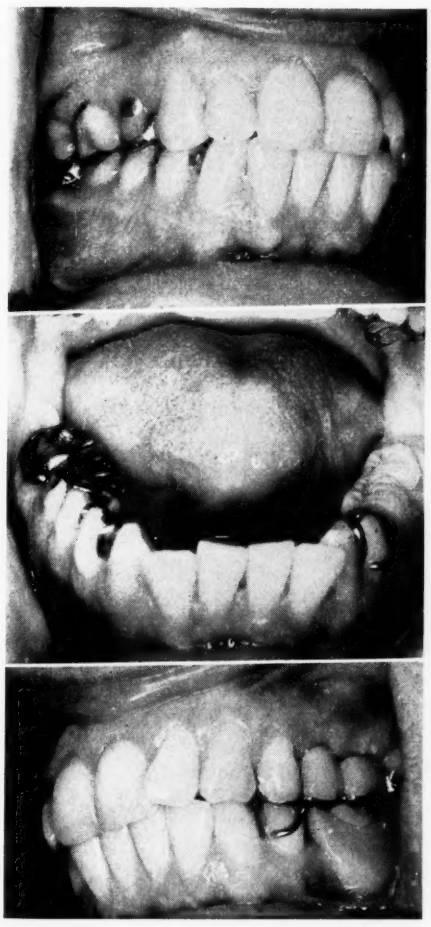

Fig. 12.

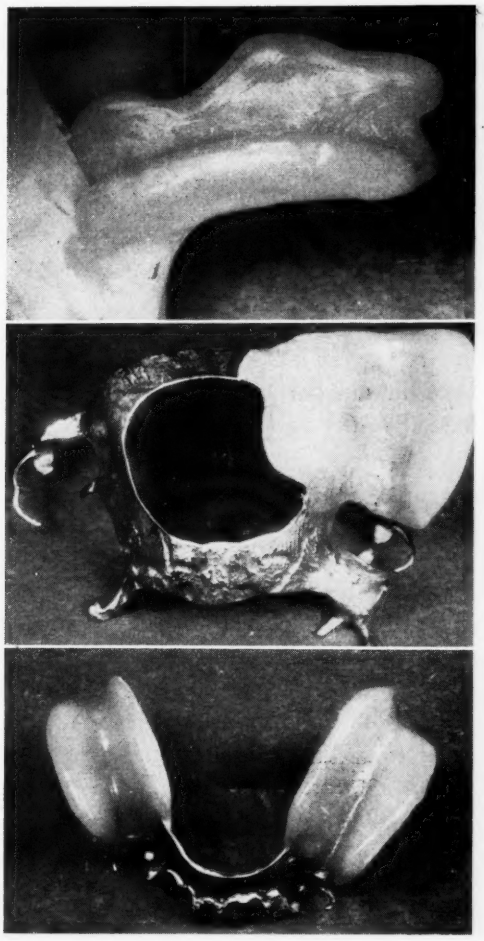

Fig. 13.

Fig. 12.—A Class II partial lower denture replacing the left molars into occlusal harmony with the remaining teeth which were first freed of areas which showed imbalance. Periodontists have been leaders in preaching the importance of occlusal harmony if oral health is to be expected to continue.

Fig. 13.—To be certain that the base of a partial denture of the extension type provides *maximum* coverage, the correctable impression permits ideal adjustment of its borders to harmonize with peripheral tissue movements. A base made to this registration will require little postinsertion adjustment. Above: Very irregular borders of a lower partial denture base. The impression (in a resin tray) has been positioned on the master cast from which the edentulous areas have been removed. Center: A correctable impression of a maxillary arch, using fluid-wax, which is supported on the cast framework of the partial denture. Below: The correctable impression method applied to the rebasing of a partial denture.

can be most accurately delineated by following an impression procedure which permits maximum adjustment at the time it is being made—in other words, a correctable impression (Fig. 13). Second, the amount of stress which is produced on the occlusal surface of the supplied teeth can be reduced. This modification of the occlusal table can be of even greater importance than the extension of the base in controlling ridge resorption during this critical period of the partial denture use.

In line with this precaution, it is suggested (in addition to achieving perfect occlusal balance) that the buccolingual width of the *supplied* teeth be greatly reduced during the early months of usage. After the teeth are positioned to a balanced relation, grind them to make them *much narrower.* In reducing the width of the lower posterior teeth, a sloping buccal surface should not be developed. Food still would be engaged on such inclines to augment the work load. Instead, the buccal surfaces of the posterior teeth should be ground so as to present a more nearly vertical slope. It is a further advantage to leave that part of the occlusal table which has the best relation to the supporting ridge surface. If the force trajectory is received in a right angle direction to the ridge surface, it will generate the least displacement of the base. Generally speaking, the poorer the bone response to previous stress loads in other sectors of the same arch, and the greater the loss of ridge tissue before replacement of the missing teeth, the greater should be the reduction of the occlusal table allowed during the *initial* period of appliance usage.

The new work stimuli, transmitted through the appliance base, will hasten a reorganization of the alveolar ridge tissues. There will be a thickening or reinforcing of the trabeculae of the area and, perhaps, the formation of some new trabecular patterns as a response to the added work stimuli received through the base. The important thing is to keep this work load as a *stimulant* and not allow it to become an *irritant.* A light occlusal work load is a stimulant, encouraging tissue tonus, while a heavy overload may become a tissue irritant which promotes atrophic change. In a few months after the insertion of a partial denture, where there has been previous disuse, the ridge becomes more stable. But, even when the initial occlusal load has been restricted, there usually will be need for reconditioning the appliance base (rebasing). At this time, new teeth can be placed on the restoration to allow a greater width of occlusal surface if conditions warrant.

This suggested reduction of occlusal width does not mean less ability to masticate efficiently—it means only that *more lateral jaw excursions* are necessary. The force resulting from contact with a food bolus in any one position will be less, and the resulting stress engendered is proportionally reduced. It encourages more cutting, less grinding. There is more of a shearing action, less of mortar-pestle mashing.

In instances where there has been a history of long disuse, where the patient's physical condition suggests a reduced metabolism, where a poor ridge form will tend to instability of the appliance, then drastically reduce the buccolingual width of the teeth which are supplied. There then will be less discomfort and much less ridge reduction under the free-end base of the partial denture.

It is not enough to achieve good tissue recovery where local areas of periodontitis previously existed; we must plan oral rehabilitation so that functional stress loads may be kept safely within the individual's limit of tissue tolerance, and this

requisite will need to be continued through a constantly lengthening average span of life. Oral rehabilitation must be attuned to this increasing longevity, as well as to possible changes in tissue tolerance during the life of the individual.

REFERENCES

1. Applegate, Oliver C.: Essentials of Removable Partial Denture Prosthesis, Philadelphia and London, 1954, W. B. Saunders Co., pp. 200-217, 277-293.
2. Applegate, Oliver C., and Nissle, R. O.: Keeping the Partial Denture in Harmony With Biologic Limitations, J.A.D.A. **43**:409-419, 1951.
3. Glickman, Irving: Clinical Periodontology; the Periodontium in Health and Disease, Philadelphia and London, 1953, W. B. Saunders Co., p. 76.
4. Ramfjord, Sigurd: University of Michigan, Lecture Notes.
5. Sicher, Harry: The Biology of Bone and Bones, Tufts College Periodontal Conference, Lenox, Mass., June 20, 1955.
6. Sommer, R. F., Ostrander, F. D., and Crowley, M. C.: Clinical Endodontics; A Manual of Scientific Endodontics, Philadelphia and London, 1956, W. B. Saunders Co., Chap. 19.
7. Tylman, Stanley: The Prosthetic Prescription for the Periodontal Patient, Tufts College Periodontal Conference, Lenox, Mass., June 23, 1955.

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THE LOWER DISTAL EXTENSION PARTIAL DENTURE USING THE HART-DUNN ATTACHMENT

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VARIOUS SOLUTIONS TO THE distal extension partial denture problem have been described by Roach,[1] Neurohr,[2] Schopper,[3, 4] Branzi and associates,[5] and others. Dunn[6, 7] offered a new approach to the stabilization of partial dentures by using wires inserted into the interproximal embrasures just under the contact points. These were used to stabilize a *transitional* or *temporary* partial denture which was to be inserted immediately after extraction to preserve esthetics. It was to be worn only until the form of the tissues had become stabilized enough to allow construction of the permanent prosthesis.

It remained for Hart,* however, to prevent the settling of the wires into the interproximal papillae and to stabilize the "embrasure hooks" by adding occlusal rests. He first used this principle in distal extension partial denture construction by utilizing the Hart-Dunn attachment on the abutment of the opposite (denture base) side.

This article will describe the technique for using a Hart-Dunn attachment to stabilize a distal extension partial denture. The attachment can be utilized with equal effectiveness on maxillary and mandibular partial dentures.

SELECTION OF ABUTMENT TEETH

Either a second bicuspid or a first molar can be selected to engage the Hart-Dunn attachment. It is preferable to locate the attachment in a fixed bridge pontic or a crowned tooth, but this is not essential. Occlusal rest seats are prepared mesially and distally to the embrasures which are to be used. These occlusal rest seats are more shallow and do not extend as far toward the center of the tooth as conventional occlusal rest seats. They also extend onto the occlusal surfaces of the teeth, adjacent to the one to be engaged by the Hart-Dunn attachment, so that a "bridging effect" is achieved with the occlusal rests. No preparation of the embrasures is required. The abutment tooth on the denture base side can be prepared either for a conventional clasp or for a precision attachment.

SURVEYING

Because the Hart-Dunn attachment is inserted in a horizontal direction just prior to seating the clasp on the denture base side, the conventional surveys as

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*E. R. Hart, personal communication.

described by Schmidt[8] are of little value. Instead, a divider is used for surveying the cast. One point of the divider is placed on the center of rotation for the attachment (at a point midway between the embrasure hook and the occlusal rests), and the other end of the divider is swept over the buccal and lingual surfaces of the abutment tooth on the opposite side and over the lingual denture base area (Fig. 1) on the study cast. Either a precision attachment or a circumferential clasp can be utilized on the denture base side to lock the partial denture in position. However, *these retainers must be on the arc scribed by the divider* (Fig. 2),

Fig. 1.—Cast survey. Note how one point of the divider is at the rotation center of the Hart-Dunn attachment. The other point sweeps over the buccal surface of the tooth to be clasped and indicates freedom from objectionable undercuts.

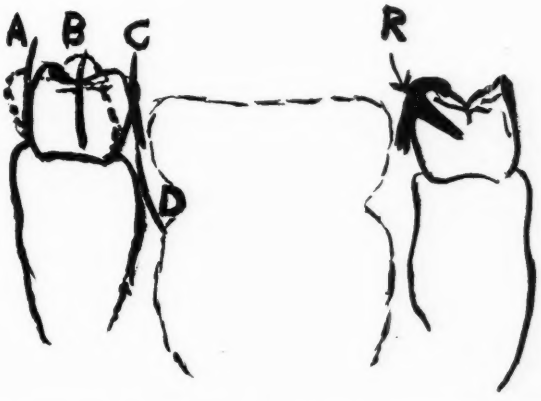

Fig. 2.—The arcs described by dividers (Fig. 1) on the abutment tooth and denture base. *A*, The solid tooth outline indicates the ideal alignment. The buccally inclined tooth (dotted outline) presents objectionable undercuts which must be eliminated. *B*, The arc of insertion of a precision attachment. *C*, The arc of insertion of the lingual clasp arm. *D*, The lingual margin of the denture base must be finished high enough to eliminate any undercut at this region. *R*, The point of rotation of the Hart-Dunn attachment.

in order that the attachment can first be seated horizontally, then the clasp or attachment on the denture base side is seated occlusogingivally. If the abutment on the denture base side is inclined toward the buccal, it presents an undercut problem. This can be solved best by constructing a cast crown to eliminate the undercut. Care should be exercised to keep the lingual border of the denture base high enough to prevent it from engaging an undercut. If a precision attachment is used, it may be necessary to round the linguogingival angle of the male attachment to allow it to seat on the correct arc.

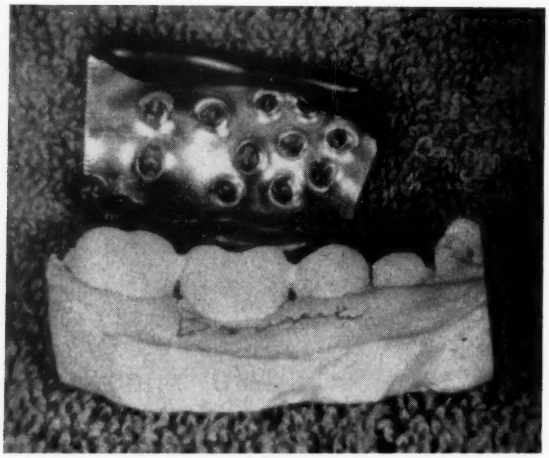

Fig. 3.—The impression tray made of air chamber metal. (Note the holes punched in the metal with a rubber dam punch. These holes lock the alginate impression in the tray and modeling plastic on the rim insures a sufficient bulk of alginate.) A cast which is used for final fitting of the Hart-Dunn attachment is obtained from the impression. Note the detail in the interproximal embrasure areas.

IMPRESSIONS

A complete alginate impression which includes all detail of the entire proposed denture area is used for making the master cast. Since it is very difficult to record the correct interproximal detail from an impression which is withdrawn occlusally, an additional impression is made to record the occlusal rest areas and the interproximal embrasures in minute detail. A small tray is fashioned from air chamber metal, and retention for the alginate is effected by punching holes in the metal with a rubber dam punch (Fig. 3). Modeling plastic is adapted to the occlusal and gingival margins of the tray to provide a definite seat and adequate bulk of alginate impression material. The tray should extend over at least one tooth on each side of the abutment tooth selected, and it should stop short of the buccal surfaces. The tray is filled with the alginate impression material, additional alginate is wiped into and through the interproximal embrasures, and the filled tray is seated. After the alginate has set, the excess impression material in the *buccal* embrasures is removed so that when the impression is withdrawn lingually, a perfect impression of the lingual embrasure as well as the occlusal surfaces of the

tooth selected is obtained. The cast poured from this impression is then used to refine the embrasures in the master cast (Fig. 3) and for the final fitting of the Hart-Dunn attachment after casting.

CASTING

Undercuts are blocked out and the master cast is duplicated in a refractory investment. Hart* suggests drilling holes in the refractory cast to carry 18 or 19 gauge round clasp wires at a 35 degree angle from the occlusal plane. The wires are placed just under the contact areas in the mesial and distal embrasures of the selected abutment tooth (Fig. 4). The wires should be curved to allow easy insertion and protection of the interproximal papillae. Plastic pins* have been inserted and used in a similar manner. The skeleton can be cast either with mesh for acrylic resin denture bases or with complete metal bases with tube teeth. Either stainless steel or gold can be utilized, although gold is preferable.

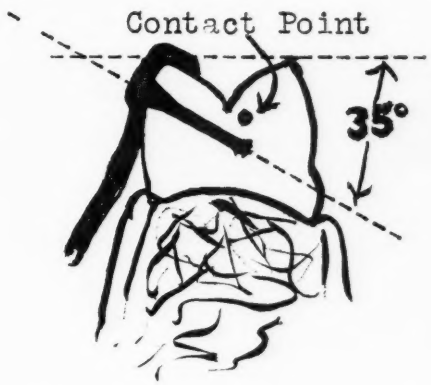

Fig. 4.—The embrasure hook is placed at a 35 degree angle to the occlusal plane.

FINISHING

After casting, the Hart-Dunn attachment is carefully finished on the small cast so it fits accurately without binding. It is then fitted to the master cast (Fig. 5), and the appliance is completed in a routine manner (Figs. 6 and 7). In seating the appliance in the mouth, the Hart-Dunn attachment must seat first, then the denture base and abutment clasp are seated on the survey arc. The denture is removed in just the opposite manner.

VARIATIONS

The dentist may choose to use either a precision attachment or conventional clasp on the denture base side. Either will work very effectively. Humphreys,[9]

*E. R. Hart, personal communication.

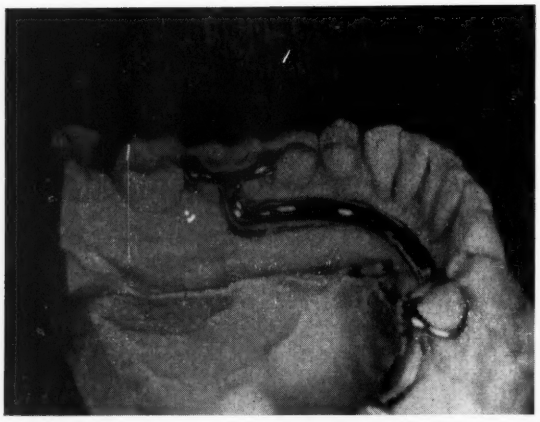

Fig. 5.—The casting is fitted first to the small cast and then to the master cast. Note the detail of the occlusal rests.

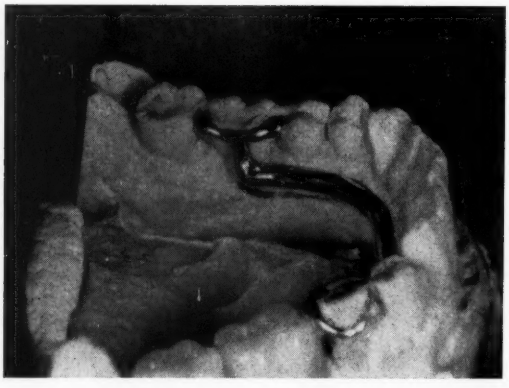

Fig. 6.—The finished partial denture on the cast. Note the restoration of functional occlusion.

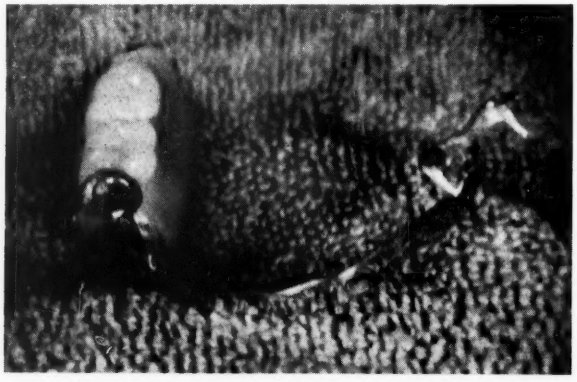

Fig. 7.—The finished denture. Note the detail of the embrasure hooks of the Hart-Dunn attachment.

Hollenback,[10] and Pankey[11] utilize a hook fitted into the pontic casting of a fixed bridge instead of embrasure hooks. One manufacturer* supplies a conventionally fabricated hook for the same purpose.

MOUTH HYGIENE

Interdental stimulation, twice daily with a round wooden toothpick as described by Westbrook,[12] McKenzie,[13] Chace,[14] and others, and diligent brushing of the lingual areas by Charter's method, with a Twinhead† toothbrush as described by Dement[15] is essential to prevent recurrent caries and also to keep the gingival tissues healthy. *Diligent home care is essential to oral health with any partial denture.*

DISCUSSION

The use of this attachment provides stable unilateral partial dentures which the patient is unable to "play with." It not only prevents the upper teeth from extruding but supplies an astonishingly efficient masticatory surface. Thus, it appears that utilizing this attachment offers a good solution to the problem where one side has a sound distal abutment tooth and the other requires a distal extension denture base. A bridge (fixed partial denture) can be constructed on the one side, and a removable distal extension partial denture can be made to lock into the pontic of the fixed bridge on the other. This is much more effective than any design which involves the use of a bilateral partial denture.

SUMMARY

1. The Hart-Dunn attachment utilizing an embrasure hook on a bicuspid or molar opposite the distal extension denture base has been described.

2. The method of surveying for the construction of this restoration has been described.

3. A small embrasure impression is used in addition to the complete arch impression in order to make the master casts for the construction.

4. The technique for casting, finishing, and completing the unilateral partial denture has been described.

5. Possible variations in the design of the partial denture have been discussed.

The author gratefully acknowledges the help of Dr. E. R. Hart in the preparation of this manuscript.

REFERENCES

1. Roach, F. E.: Mouth Survey and Design of Partial Dentures, J.A.D.A. **21**:1166, 1934.
2. Neurohr, F. G.: Spring Lock and Insertion Pin Lock Attachments in Saddle Designs for Partial Dentures, J.A.D.A. **23**:1530, 1936.
3. Schopper, A. F.: Value of Stressbreakers for Unilateral Partial Dentures With Free End Saddles, J.A.D.A., **38**:185, 1949
4. Schopper, A. F.: Value of Stress Breaker for Unilateral Partial Dentures With Free End Saddles, J. South. California D. A. **23**:34, 1955.

*Williams Gold Refining Co., Buffalo, N. Y.
†Lactona, Inc., St. Paul, Minnesota.

5. Branzi, A., and Zuccoli, G.: The Problem of Unilateral Removable Appliances, J. Philippine D. A. **6**:9, 1953.
6. Dunn, A. L.: A Safe Temporary Partial Denture, J.A.D.A. **23**:96, 1936.
7. Dunn, A. L.: A Safe Transitional Partial Denture, D. Digest **45**:64, 1939.
8. Schmidt, A. H.: Planning and Designing Partial Dentures, D. Digest **54**:444, 1948.
9. Humphreys, Karl: Removable Bridge Using a Hook Attachment in a Tinker Pontic, J. California D. A. **2**:372, 1935.
10. Hollenback, G. M.: Personal communication.
11. Pankey, L. D.: Personal communication.
12. Westbrook, J. C., Jr.: A Pattern of Centric Occlusion, J.A.D.A. **39**:407, 1949.
13. McKenzie, J. S.: Some Periodontal Considerations in Partial Denture Planning, J.A.D.A. **45**:314, 1952.
14. Chace, R.: Personal communication.
15. Dement, R. L.: Home Care of the Mouth and Its Importance, Fort. Rev. Chicago D. Soc. **24**:11-14, 1952.

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RESIN TRANSFER COPINGS

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IN CERTAIN CROWN AND BRIDGE procedures, it is necessary to make use of transfer copings for proper die orientation. Various metals and waxes have been used successfully for making such copings, but the self-curing resins offer several distinct advantages. Two of the most significant advantages of the self-curing resins are the ease of fabrication of the coping and the accuracy of the centric relation registration, which can be accomplished in combination with the transfer impression.

The purpose of this article is to describe the laboratory and chair procedures involved in the use of resin copings.

COPING FABRICATION

All tooth preparations in one dental arch are completed, and copper-plated dies are constructed. Each die is coated with a suitable separating medium, and a mass of self-curing resin is built up to cover the preparation. After bench curing, the resin copings are trimmed to approximate crown proportions, but sufficient undercuts are developed on their outer surfaces to assure their retention in the impression material, which is to be used later in the mouth. It is advisable to grind a hole in the occlusal surface of the coping to assure its complete seating on the prepared tooth (Fig. 1).

IMPRESSION AND JAW RELATION REGISTRATION

All of the copings are tried in to make sure that they seat properly on their respective preparations without interference with the adjacent teeth or each other. The refinement of the gingival margins and of the occlusal and proximal surfaces is accomplished by grinding. All copings are reduced occlusally until they are just out of contact with the opposing teeth in centric occlusion. This means that only the remaining natural teeth are used to maintain the occlusal vertical dimension. A small mound of self-curing resin is built up on the occlusal surface of each coping, after a small drop of utility wax has been placed over the previously made hole to prevent seepage of the new resin. The opposing teeth are lightly lubricated. The patient is directed to close into centric occlusion and to maintain this jaw position until the resin hardens (Fig. 2). Upon separation of the occluding surfaces of the teeth, it will be noted that each coping has a definite imprint of

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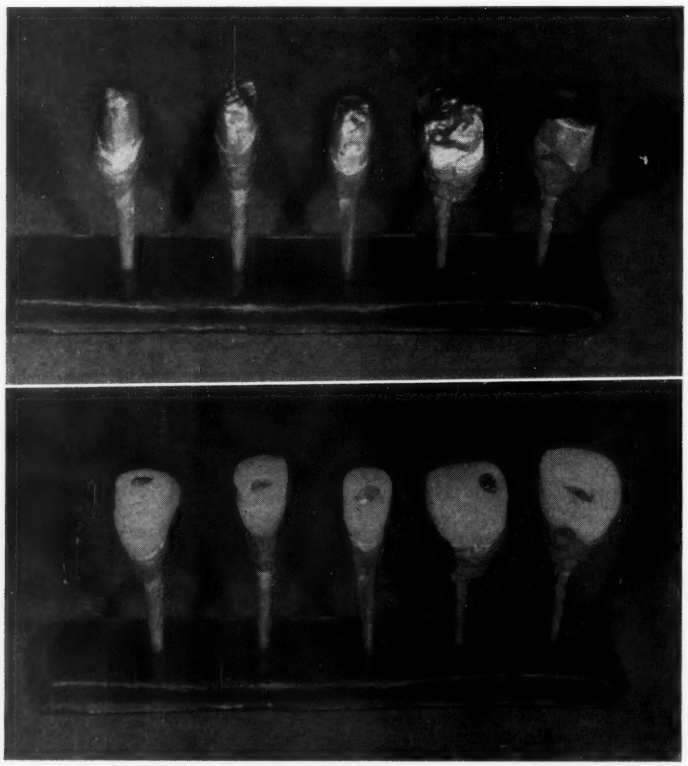
the opposing tooth or teeth. This is the only record necessary for the registration of centric occlusion. These occlusal seats and the remaining natural teeth will afford a completely accurate guide for the articulation of the casts in the laboratory.

A.



B.

Fig. 1.—*A*, The completed copper-plated dies for all the preparations in one dental arch. *B*, The resin copings on the dies are ready for the try-in.

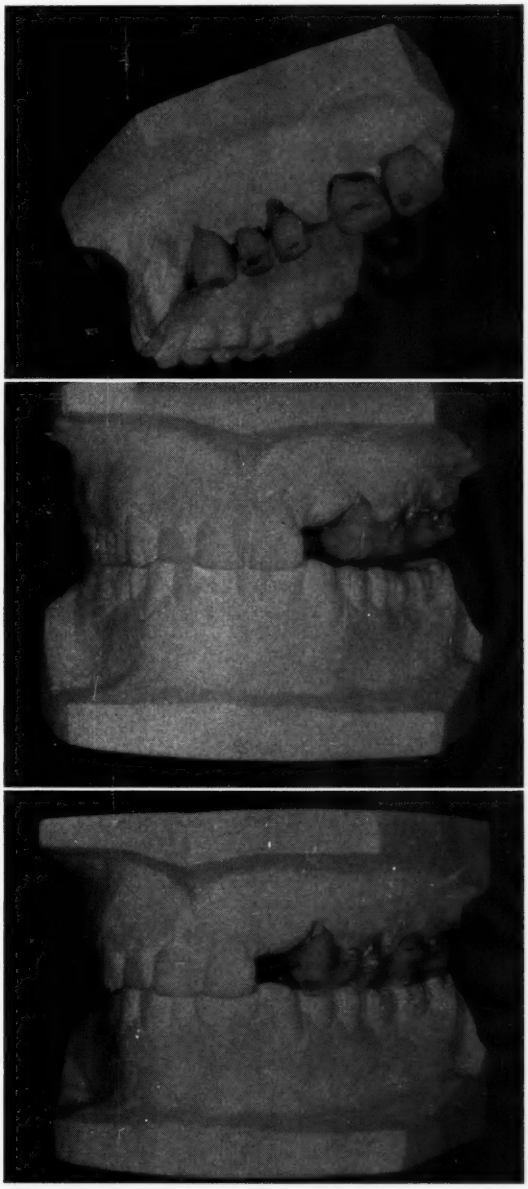
With the finished copings firmly seated on the prepared teeth, an impression is made of the entire dental arch. Plaster of Paris, or a combination of plaster of Paris and an alginate type of hydrocolloid material, is used for this over-all impression. All of the copings should be imbedded in plaster of Paris to prevent die movement while the working cast is being poured (Fig. 3). An impression of the opposing dental arch is made with an alginate impression material.

The casts are occluded in the laboratory and used for making the individual crowns only. The finished crowns are seated on their respective teeth in the patient's mouth, and new dental arch impressions are made if the crowns are to be used in connection with fixed or removable partial dentures.

DISCUSSION

Various deviations and modifications from this technique for using resin copings become necessary in order to meet different clinical situations. For example,

in a complete arch restoration where all the remaining teeth in one arch undergo preparation, there remains no guide to the occlusal vertical dimension. In such instances, two of the copings, one on each side of the arch, can be built to the



A.

B.

C.

Fig. 2.—Casts representing the patient's dental arches and showing the procedure at the chair. *A*, The copings are fitted on their respective teeth. The hole in the coping will assure proper seating. *B*, The occlusal arches in centric occlusion showing that the copings have been adjusted so that they are out of contact with opposing teeth. *C*, The dental arches in centric occlusion after the excess mound of resin has been added to the occlusal surface of the copings.

proper occlusal height and used as stops. These stops will provide the patient with something to close against and thus maintain the occlusal vertical dimension, while the centric relation registration is made on the remaining copings.

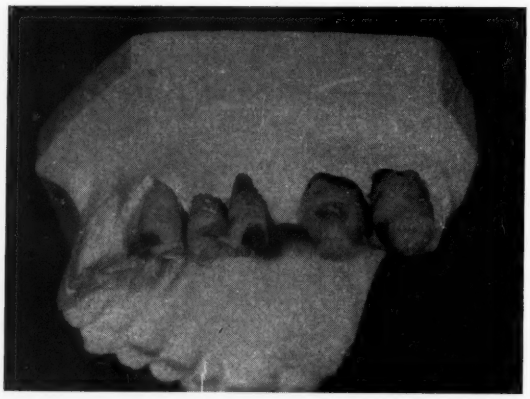


Fig. 3.—A working cast is obtained from the transfer impression. Note the occlusal seats on the copings which will accurately occlude with the teeth on the opposing cast.

CONCLUSION

The fabrication of resin copings and their use in acquiring a registration of centric occlusion have been described. The accuracy of the contour and occlusion of crowns made with this technique indicate that it is a practical and useful crown and bridge procedure.

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CROWN AND BRIDGE ARTICULATION ON THE TRANSOGRAPH

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IT IS GENERALLY ACCEPTED by conscientious dental practitioners that the oral mechanism be treated as a single functioning organ. The interdependence of all the dental structures precludes the possibility of successful restoration unless the treatment plan encompasses the effect of the prescribed treatment in relation to the complete oral mechanism. Of primary concern are the problems of articulation. The recognition of the degree to which occlusal problems contribute to the breakdown of the normal functional pattern has fostered the development of new approaches in the study of occlusal relations. It is no longer accepted practice to depend on the adaptive capacity of the chewing apparatus to compensate for inadequate methods of articulating teeth.

The men who initiated the research in this field realized that unless they could achieve a fundamental concept of the functional movements of the jaw and develop instruments capable of reproducing these movements, their proficiency would be greatly limited. Certainly, an instrument that would aid us in reproducing mandibular movements with a degree of accuracy, and which would enable us, figuratively, "to place the patient's head on the laboratory bench"* would be invaluable. Diagnostic evaluation of study casts would then be more valid than utilizing the casts in their static relationships. Restorations could be constructed in the laboratory and placed in the patient's mouth with a minimum of adjustment.

In 1926, McCollum[1] and the Gnathological Society of California presented to dentistry new concepts of articulation. At the same time, this group began to develop instrumentation to enable it to apply the functional aspects of its theories. Since that time, they and their adherents have been continually changing and adding to the original instruments and recording apparatus. Their fundamental theories are the basis for transographics, but the applications are entirely different. In the instruments emanating from the Gnathological Society, a recording device is used which can trace pantographs of mandibular motion. By placing an articulating instrument within the same pantographic tracing and reversing the procedure, the instrument is adjusted in an attempt to follow the pantographic writings. The purpose of this process is to reproduce three-dimensional rotatory movements of the mandible in function. With some other instruments, only the transverse hinge axes recordings are accepted; the other dimensions of movement are either accepted as averages or are arrived at by a system of interocclusal records.

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*R. N. Albinson, personal communication.

For the Transograph, however, the claim is made that by starting with the fundamental transverse axes recordings and properly orienting these to cranial structures, it can duplicate the remainder of the functional movements accurately by the use of mechanical equivalents. The simplicity and ease of adjustment of the Transograph are, in themselves, an endorsement of the instrument. Its fundamental importance to the dental profession is, of course, the accuracy with which the desired result can be achieved.

Unfortunately, clinical results must enter into the evaluation of any biomechanical procedure. Highly capable men in the field of restorative dentistry use variations of many techniques. These dentists would not use these procedures unless they felt that by using them they were able to give their best efforts to their patients.

Essentially, dentistry is concerned with the articulation of teeth. The masticatory apparatus must operate in such fashion as to produce the most efficient function without damage to the teeth, the periodontal structures, or the condylar mechanism.

Transographics is a concept that is helpful to the achievement of this end. Transographics is based upon kinematics, that is, the reproduction and control of preconscious, functional jaw movements.

MASTICATORY MOVEMENTS

The movements of the mandible in the act of mastication are considered to be those involved in preparing the bolus for chewing and those involved in the terminal functional orbit. The preparatory movements are extremely erratic and are of no particular importance because, during this phase of masticatory function, no tooth contacts are made. This phase includes all lateral and protrusive movements. The mandible is moving from protrusive or lateral protrusive positions to so-called centric position. As soon as the bolus has been prepared for trituration, the character of the function changes. There is now a rotary-translational movement of the working condyle and a translational movement of the occlusal surfaces of the mandibular teeth, with the mandible dropping down and back, away from occlusal contact. The closing stroke, with which we are primarily concerned, moves the mandible upward, inward, and forward. In the preparatory motions, both condyles are out of their hinge positions. In the final closure (the terminal functional orbit*), the condyle on the working side is braced in its hinge position on the anterior slope of the mandibular fossa. As the condyle rotates and the mandible translates on the working side, the condyle on the balancing side is being returned to its hinge position in the fossa. As long as the angle of closure is steeper in the transverse plane than the cuspal angulation of the teeth, there will be no contact of teeth until the tips of the cusps contact in the bottoms of the fossae. The cuspal inclines do not come into contact during the terminal functional stroke but act as efficient shearing mechanisms. The cuspal tips are driven through the bolus until final contact or the interposed food particles are no longer compressible or displaceable. All of the force is then directed through the long axes

*Theodore Messermer, personal communication.

of the opposing teeth. During the fleeting moment of maximum muscle contraction, the mandible is supported by the full dentition and by both condyles in their hinge positions.

If this theory of mastication is correct, it could account for many previously unexplained formations of occlusion. As one example, a seemingly jumbled arrangement of natural teeth that exhibits no sign of pathology will, when analyzed from a transographic mounting, be found to have perfect cuspal incline coordination and centric occlusal contact in accord with condylar rotational movements. One set of surfaces of the teeth are occluded when the mandible closes upward, mesially, and protrusively; another set is contacted when it moves from a lateral position into retrusion. It is recognized that teeth can be contacted in lateral and protrusive positions, although this is nonfunctional. It is only essential to provide maximum distribution of contact in these nonfunctional positions in order to prevent the overloading of individual teeth, if the patient should indulge in bruxation.

The Transograph provides the means for carrying out this concept. Admittedly, the needs of the dental profession are such that instruments alone do not solve all its problems of occlusion and articulation. The Transograph is a very useful apparatus in the hands of the men who have included it in their treatment procedures. It is a flexible mechanical monitor which will permit individual patterns of occlusion. By using it intelligently and with a full understanding of the theories it represents, the dentist can develop the desired functional occlusion and articulation.

Even though we are particularly interested in the applications pertaining to the natural dentition, the principles of articulation are the same in any field of dentistry. The instrument is used in the identical manner whether it be in analysis of natural occlusion or in the construction of fixed restorations and complete dentures. The old idea that one type of occlusal anatomy would serve in complete denture construction but another type must be utilized in the treatment of a natural dentition has been proved false.

PRINCIPLES OF TRANSOGRAPHICS

There are certain principles on which transographics is based. It is concerned with four elements: (1) the hinge axes, (2) the cranial plane, (3) the Bennett movement, and (4) the envelope of motion. The methods of locating the transverse hinge axes are common knowledge. These axes are the origins and terminals of all condylar functional movements. When the hinge-bow is in position, the axle rods of the locator are rotating along these axes, which are parallel but not in the same plane anteroposteriorly or superoinferiorly.

A cranial plane must be incorporated in the instrument to insure off-sagittal movements which are accurately correlated to the articulation.

The term "Bennett movement" has many interpretations. Primarily, it is a bodily shift of the entire mandible in any one or all three dimensions. A simple parallel is a crankshaft with bearings that are untrue. In fixed, rigid machinery, this irregularity would result in torque of the shaft until the bearings were worn out. Fortunately, in the temporomandibular joint, the looseness of the capsular

ligaments permits the asymmetry noted in the axes recording to result in a bodily shift of the mandible without pain or destruction. In the Transograph, there is a mechanical equivalent of this movement. This is readily accomplished because the instrument is slightly flexible.

The last movement to be duplicated is the angle in the transverse plane along which the subject's functional pattern travels during final closure. This is done by the use of an adjustable jaw movement guide. This guide makes it possible to reproduce the flattest closure angle of the functional pattern. The angles to which this guide is adjusted are experiential. This action continually shifts the vertical, sagittal, and transverse axial centers (by instrument flexing) into composite positions that are equivalent to the positions they assume in the head as the jaw moves along corresponding paths. The Transograph, having correlated the hinge axes to the cranial plane and the Bennett movement, functions around three-dimensional control centers that are equivalent to the same control centers, or hinge axes, in the head. Its envelope of motion is the same as the patient's envelope of motion; therefore, any functional movement the mandible is capable of making is duplicated on the instrument.

It should be noted that the term "mechanical equivalent" has been used several times. The use of this term has caused many men to doubt the validity of the Transograph. The reproduction of mandibular motion is the important factor, not the method of registration.

In systems where recordings are taken with the teeth in contact, even if contact is established by means of a central bearing point, the mandibular movements recorded are those that occur after functional closure. The movements recorded are away from "centric position," and any adjustments to an articulator made from these recordings assume that the paths of closure from an open to closed position are identical to nonfunctional radial lateral movements. As yet, any of the conventional methods for locating exactly the rotational centers have proved either too cumbersome to be of any practical value to the profession in general or to be so indirect that they predispose to the introduction of errors.

The Transograph and the concepts upon which it is based have been tested in practice by many meticulous operators. Their findings have confirmed the accuracy of the Transograph as an instrument and established the validity of the concept of transographics.

REFERENCE

1. McCollum, B. B.: Diagnosis and the Fabrication and Application of Dental Remedies, Pacific Dental Gazette **34**:744-758, 1926.

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THE THEORETICAL AND FUNCTIONAL EVALUATION OF HIGHER SPEED ROTARY INSTRUMENTATION

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SINCE THE RAVAGES OF DENTAL caries first made their appearance in the human dentition, men have been searching for means of cutting tooth structure for repairing and restoring the evident damages. Whether it was the witch doctor or traveling charlatan, their problems existed for the necessary treatment even though their concept of dental service was nothing more than being a "tooth carpenter." From these very early beginnings to the era of organized dentistry, the concepts of dental treatment have changed, but the basic problem of a more effective means of cutting tooth structure has remained the same.

The earliest effort to cut teeth was by the use of an abrasive hand tool or file, which was subsequently followed by the invention of a hand rotary drill, a foot engine rotary drill,[1] and electric motor drilling of very slow rotation at about 1,500 r.p.m. These developments evolved over many hundreds of years, but within the last fifty years, the changes in rationale have increased many fold (Fig. 1). It is with this in mind that, in the past two decades, the innovations have caused much confusion, doubt, reluctance, and dissension in the minds of the members of the dental profession as to the best means of accomplishing the task.

In 1942, Black[2,3] began his investigations and development of a procedure which is known today as the airbrasive technique. This method was a pioneer effort in the elimination of patient objections to dental treatment, even though limitations exist in its application.[4, 5] Concurrently, investigations in the field of rotary instrumentation were explored. The tools of industry, such as tungsten carbide burs and diamond instruments, and crude methods of cooling[6] were employed for the more effective removal of tooth structure. Although this improvement took place, the valid patient objections remained the same because the basic speed of about 3,000 to 4,000 r.p.m. was still maintained.

In the last five years, many changes in instrumentation involving increased rotary speeds and improvement in cutting tools and the ultrasonic principle have been placed in the hands of dentists. Many articles and researches have been published and completed to determine the various values of these innovations.[7, 16] But the general practitioner, because of limited time to delve into these findings, is in a quandary as to the selection of equipment and tools to further his progress.

Therefore, it is incumbent that information be provided to act as a guide so that a dentist may determine the procedures, instruments, and materials best suited

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to his particular needs. It is the purpose of this article to delineate a working outline so that the mass of the available material can be summarized and utilized.

ROTARY INSTRUMENTATION

Rotary instrumentation can be divided into four main categories for the purpose of discussion. They are: (1) conventional speed—3,000-6,000 r.p.m., (2) medium high speed—10,000-20,000 r.p.m., (3) high speed—20,000-45,000 r.p.m., and (4) ultra high speed—100,000 r.p.m. or above rotation.

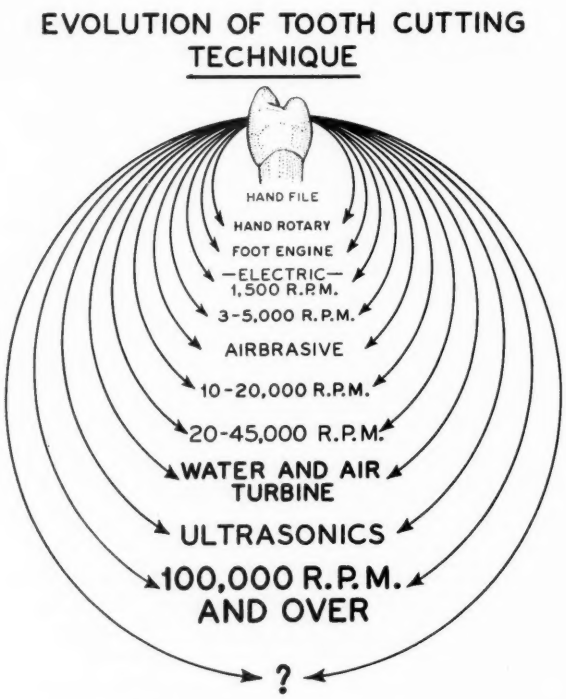


Fig. 1.—The evolution of tooth-cutting technique.

Each of these categories calls for the understanding of the armamentarium necessary to cope with the problems at these various speeds, as well as an understanding of the advantages and disadavantages of each.

For an understanding of these problems, and as a basis of comparison, there are certain fundamentals applicable to each category.[17] These are (1) speed and surface feet per minute, (2) pressure, (3) heat production, (4) vibration, (5) instrument design, (6) patient reaction, (7) operator fatigue, (8) efficiency, (9) economics, (10) adaptability of standard equipment, and (11) practical application.

SPEED

An explanation of the term speed is needed for a more complete understanding of rotary instrumentation. Many practitioners have been under the assumption

that increase of motor speed or revolutions per minute is the objective for better cutting. However, speed is relative only to the amount of milling or grinding surface brought in contact with the tooth per unit of time. This is defined as surface feet per unit of time of contact and is explained by the following formula:

Time $\times$ revolutions per minute $\times$ 2 π $\times$ radius of cutting tool = linear surface feet per unit time. Or expressed symbolically: T $\times$ r.p.m. $\times$ 2πR = LSF/per unit time, where

T = time
R = radius
r.p.m. = revolutions per minute
W = width of instrument
D = diameter
LSF = linear surface feet
2πR = surface feet of cutting tool or circumference

Since the width of the cutting tool is a consideration in the amount of tooth structure removed, the formula expressing this factor is as follows:

LSF/per unit time $\times$ W = milling or grinding surface in contact per unit time.

For example, if a stone one-half inch in diameter is used with a speed of 3,000 r.p.m. for 2 minutes, the linear surface feet of contact for the 2 minutes would be:

T $\times$ r.p.m. $\times$ 2πR = LSF/unit time
2 $\times$ 3,000 $\times$ 2 (3.1416) $\times$ 1/4 = 9,420 inches
or to convert to feet
9,420 $\div$ 12 = 785 surface feet per unit time.

If a cylindrical mounted stone 1/12 inch in diameter is used with a speed of 100,000 r.p.m. for 2 minutes, the linear surface feet of contact for the 2 minutes would be:

T $\times$ r.p.m. $\times$ 2πR = LSF/unit time
2 $\times$ 100,000 $\times$ 2 (3.1416) $\times$ 1/24 = 54,000 inches
54,000 $\div$ 12 = 4,500 surface feet per unit time.

According to industrial investigation, the maximum cutting efficiency of a cutting tool of uniform width ranges between 5,000 and 6,000 surface feet per minute. Therefore, from these figures, it is important to consider the size of the working tool, both as to width and diameter, in relation to speed of operation or r.p.m. The selection of a tool is predicated upon the speed of operation in order to obtain maximum efficiency and is necessary in determining the size of a tool used at the varying speeds.

As a result of these data, a rotary tool should be large in diameter at conventional and medium speeds to approach as closely as possible the optimum surface feet per unit time, whereas in the ultra high speed range, the diameter of the cutting tool should be reduced to approximate the limits of maximum cutting efficiency. Maximum cutting efficiency can be obtained by altering the size of the stone in ratio to the speed.*

PRESSURE

The term "pressure" must be defined in order to evaluate its importance in high-speed application. As the term pressure is now used, it is usually interpreted

*Speed should be considered as the r.p.m. delivered at the handpiece rather than the rotational speed of the motor.

incorrectly, and the problem of semantics enters the picture. Pressure is a resultant effect of two factors under the control of the dentist: (1) *force,* which is the gripping of the handpiece and its positioning and application to the tooth, and (2) *area,* which is the amount of the cutting tool in contact with the tooth surface during any cutting operation at any instant. This can be illustrated by the following formula: $P = \frac{F}{A}$, where F is the amount of work done by the operator in holding and pushing the handpiece, and A is the amount of the area of the cutting tool in contact with the tooth at any particular instant. P is then the resultant calculation which should be called pressure. For example, in the formula $P = \frac{F}{A}$ substitute the actual figures of a dentist using 2 pounds force and a stone having a diameter of 1 inch and width of ⅛ inch. The amount of stone in contact with the object being cut will vary according to the shape of this object. It can be assumed that a certain amount of the stone will be in contact at any given moment. To illustrate this formula, let us state that 1/32 of the stone's circumference is in contact Fig. 2).

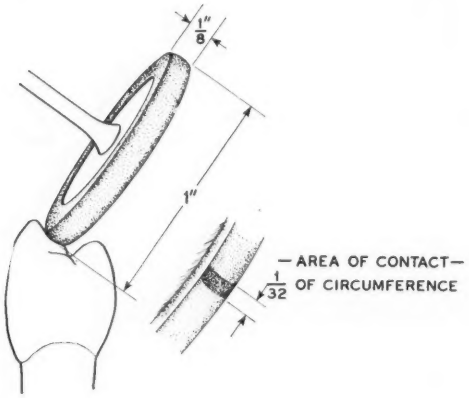


Fig. 2.

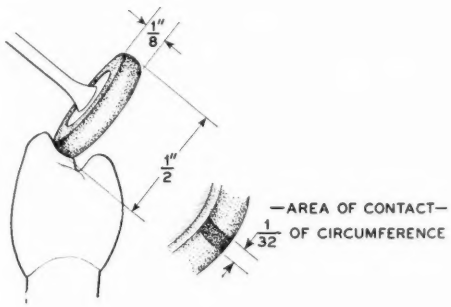


Fig. 3.

Fig. 2.—The amount of stone in contact with a tooth at any particular instant. This will vary in relation to the size of the stone and shape of the surface contacted.

Fig. 3.—A smaller stone with a reduced area of contact against a tooth.

(Circumference $= 2\pi R$)
$2 \times 3.14 \times \frac{1}{2} = C$
$3.14 = C$

to find A: $C = 3.14$
$1/32\ C = .4$ inch or 2/5 inch approx.
A = width × length
width = ⅛ given
length = 2/5 by calculation
substituting: A = ⅛ inch × 2/5 inch
A = 1/20 square inch
$P = \frac{F}{A} = \frac{2}{1/20}$ or
P = 40 pounds at point of contact.

If a smaller stone is used (Fig. 3), ½ inch diameter and ⅛ inch width with 2 pounds of force, by the above method of calculating, A = 1/40 square inch.

$$P = \frac{F}{A} = \frac{2}{1/40}$$

P = 80 pounds at point of contact

Therefore, it can be seen that when a smaller stone is used, more pressure is applied at the point of contact. It is evident that, to have both stones operate at the same pressure, it is necessary to *reduce* the force applied with the smaller stone.

If the constant force is reduced on the smaller wheel so that there is equal pressure on the tooth, obviously the larger wheel will remove more tooth structure, since there is more surface feet per minute contact. To have the smaller wheel remove the same amount of tooth structure as the larger wheel, it is necessary to increase the surface feet per minute of the smaller wheel by increasing the speed or r.p.m. *The net result of this maneuver is to have a cutting tool smaller in size with less force applied by the dentist and running at a greater r.p.m.* The

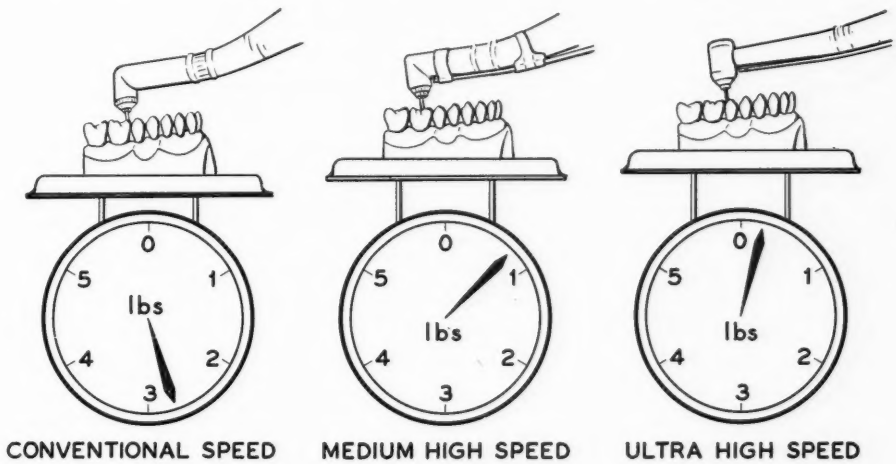


Fig. 4.—Diminution of applied force as speed is increased.

pressure at the point of contact is the same as with the larger wheel, but we have reduced the forces to be applied in controlling and operating the instrument. For this reason, it has been observed clinically and experimentally that conventional speeds require 2 to 5 pounds force, medium speeds less force (1 pound or less), and ultra high speeds still less force (a few ounces) applied by the dentist (Fig. 4). This is one of the most desirable features of higher speed rotary operation, resulting in better control on the part of the dentist, less fatigue of the dentist, greater patient comfort due to reduction of forces on the tooth, and more efficient removal of tooth structure.[17]

HEAT PRODUCTION

Heat production is directly proportional to the factors of (1) pressure, (2) r.p.m., and (3) area of tool in contact with tooth.

If any of these factors is increased, heat production is increased; and since heat production will cause pulps of teeth to be permanently damaged if temperatures of 130° F. are reached, heat must be controlled. Even a temperature of 113°F. can produce an inflammatory response resulting in pulpitis.[18-20]

It has been shown that, when the area of the cutting tool is reduced but speed of rotation is increased with pressure remaining the same, it is an absolute necessity that coolants must be employed in order to eliminate pulpal damage. This can be accomplished by the use of various types of coolant mechanisms such as water flow, water spray, or air. Much research has already been published to emphasize the importance of this need in higher speed instrumentation.[6, 7, 21, 22] It is a matter of personal preference as to the choice of a particular method of expelling the coolant, but it remains that water or water spray must be used with diamond cutting stones and points, whereas air or water spray can be used with tungsten carbide burs.

Since it has been shown that pressure is a result of applied force, a reduction of this force will minimize heat production and, since higher speeds call for less force on the part of the dentist, and since coolants are used, heat production is reduced.

A great deal of criticism has been directed at higher speed instrumentation because of this possibility of excessive heat production.[22, 23] If the proper technique of decreased force, use of a proper cutting tool for the designated speed, and the employment of coolants are utilized, then this fear of pulpal damage is unfounded, as has been shown by many investigators.[16, 17, 24]

VIBRATION

One of the important limitations of all rotary instrumentation is vibration and its effects on the tooth, the instruments used, the dentist, and the patient. Of all the factors of rotary instrumentation, vibration is the one feature that patients abhor. Vibration is also a major factor in inducing operator fatigue and excessive wear of instruments.[25]

This feature of vibration in dentistry was one of the compelling reasons for the development of other methods of cutting tooth structure, such as airbrasive, ultrasonics, and water and air turbine-driven tools.[2, 5, 11, 12, 26, 27]

In higher speed rotary instrumentation, the cause and the elimination of vibration must be clearly understood so as to enhance the value of this method of tooth cutting.

Vibration is a product of the equipment used and the speed of rotation. The equipment, namely the engine, the engine arm, the belt, the pulley wheels, the handpiece and contra-angle, and the various cutting tools all contribute to the *quantity* and *quality* of vibration[28, 29] (Fig. 5).

The deleterious effects of vibration are twofold in origin: (1) amplitude, and (2) undesirable modulating frequencies. If we can minimize or eliminate these factors, we can then reduce the undesirable effects of vibration.

Amplitude.—The wave of vibration consists of frequency and amplitude (Fig. 6). At conventional speeds, amplitude is greater but frequency is less. At higher

speeds the reverse is true. The greatest harm is caused by the amplitude of vibration which is the factor most destructive of instruments and which causes the most apprehension in the patient and the greatest fatigue in the dentist. By increasing operating speeds, the amplitude and its effects are reduced, and a more satisfactory result is attained[24, 29] (Fig. 7).

Vibration waves are measured in cycles per second. It has been shown that rotation of approximately 6,000 r.p.m. sets up a vibrational wave of approximately 100 cycles per second. This has been demonstrated to be the range most annoying to the patient and dentist. As the revolutions per minute are increased, the cycles per second of the fundamental vibration wave are increased until, at ranges of 100,000 r.p.m., we have a vibration wave of 1,600 cycles per second. In experiments conducted in vivo, it has been demonstrated that at a wave of vibration of over 1,300 cycles per second, vibration is practically imperceptible to the patient[28] (Fig. 8). The reason for this is not fully understood, but there are two theories for this phenomenon: (1) the Wedensky inhibition phenomenon holds that where stimulation occurs during the refractory period of recovery of the perceptor mechanism, no further reaction will be evident, and (2) due to light pressure and high speed, the chronaxie (the amount of stimulation multiplied by the frequency of stimulation necessary for a reaction) needed for vibratory perception, has not been attained.[20] (Fig. 9.)

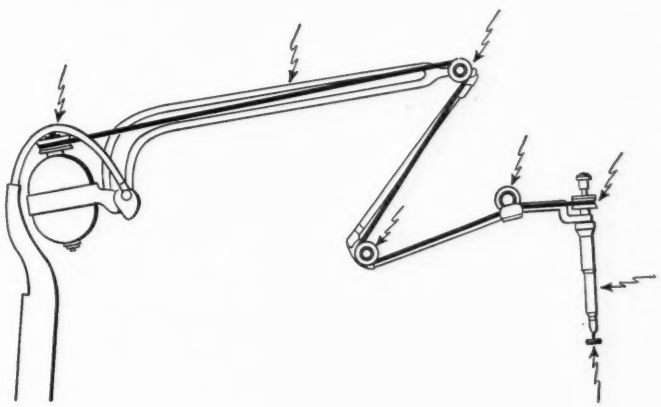


Fig. 5.—Sites of vibration emanating from the engine, engine arm, belt, pulley wheels, handpiece, and cutting tool. The use of a contra-angle produces additional vibration.

Thus is can be concluded that, the more the r.p.m., the less the amplitude, and the greater the frequency, vibratory perception will be lost in the ultra speed range of 100,000 r.p.m. or more.

Undesirable Modulating Frequency.—The second deleterious effect of vibration, undesirable modulating frequency, is caused primarily by improperly designed, worn, or poorly cared for equipment. With belt-driven equipment, regardless of its perfection, quality, and care, there must exist a fundamental vibration

wave. If, however, by improper equipment or care, we allow modulating frequencies to be set up so that a series of vibrations are perceived by the patient and the dentist, the end result is again the cause for apprehension in the patient, dentist fatigue, and wear of cutting instruments. As the fundamental vibration wave is set up when the engine is on, each piece of equipment will vibrate dependent upon

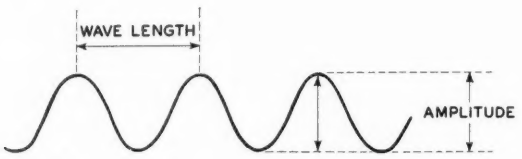


Fig. 6.

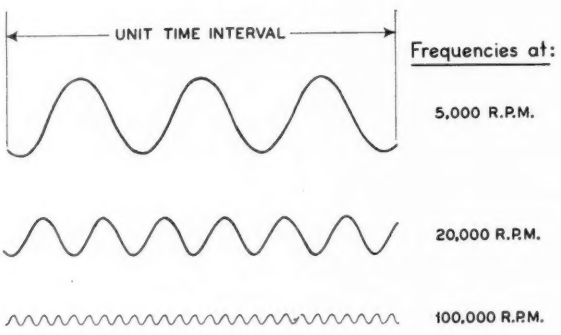


Fig. 7.

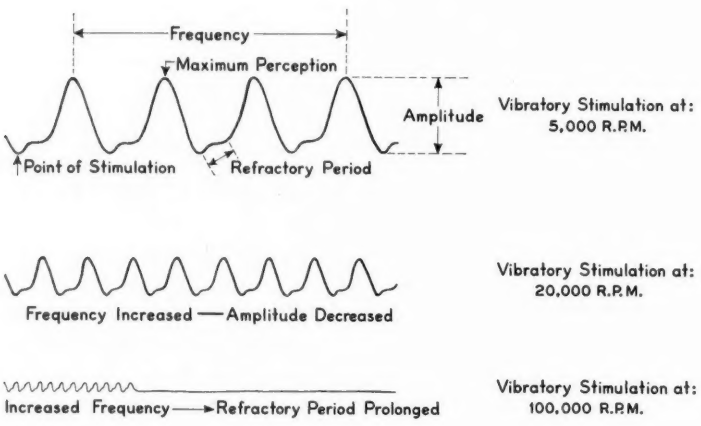


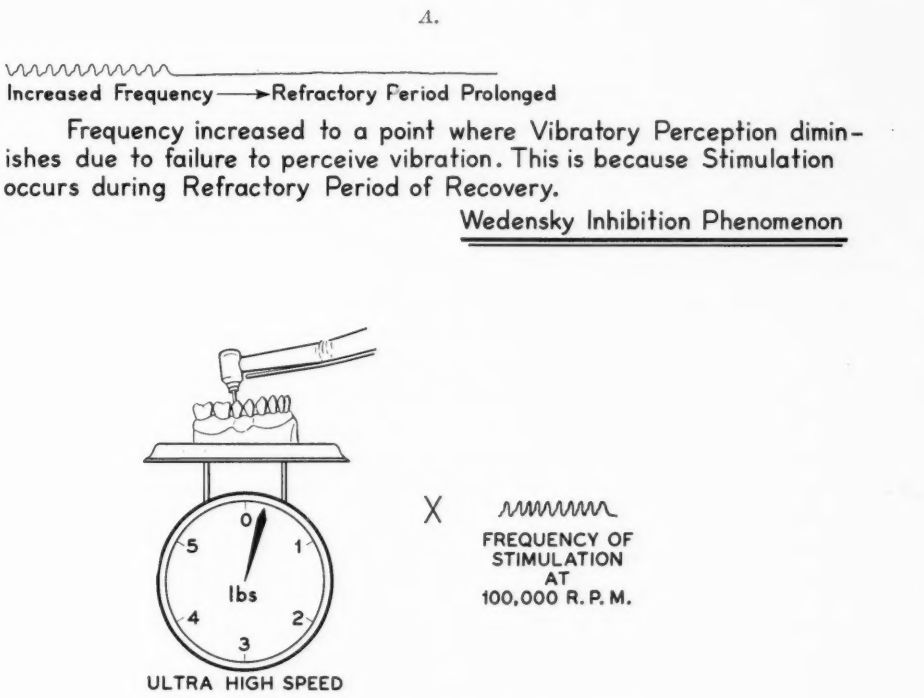
Fig. 8.

Fig. 6.—The wave of vibration consists of wave length and amplitude. The number of wave lengths per unit of time equals frequency.

Fig. 7.—Increased speeds produce decreased amplitudes and increased frequencies.

Fig. 8.—A comparison of physiologic muscle responses to a vibratory stimulus.

the amount of wear or play, or eccentricity in its moving parts. Each of these will set up a modulating frequency or overtone accompanying the fundamental vibrational wave, so that the patient and the dentist are subjected to not only the basic wave but all other accompanying phenomena (Fig. 10). It should be the objective of the operator to eliminate these by having the equipment free of any such defects. He should supply himself with a true running engine, pulleys, unworn or smooth


A.
Increased Frequency ⟶ Refractory Period Prolonged
Frequency increased to a point where Vibratory Perception diminishes due to failure to perceive vibration. This is because Stimulation occurs during Refractory Period of Recovery.
Wedensky Inhibition Phenomenon
0
1
2
3
4
5
lbs
ULTRA HIGH SPEED
X
FREQUENCY OF STIMULATION AT 100,000 R. P. M.
Light pressure multiplied by high speed may not equal the "Chronaxie" needed for Vibratory Perception.
B.

9.—*A*, A theoretical concept for the failure to perceive vibrational stimulation at ultra high speeds. *B*, Another theoretical concept for the failure to perceive vibrational stimulation at ultra high speeds.

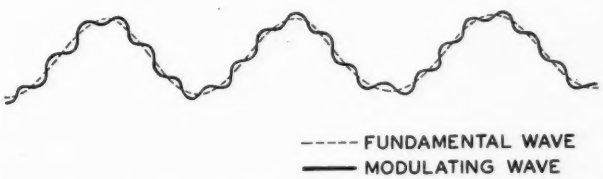


Fig. 10.—One of the deleterious effects of vibration. Undesirable modulating frequency is primarily caused by improperly designed, worn, or poorly maintained equipment.

belt, handpiece, contra-angle so manufactured as to run true at high speeds, and centric cutting wheels, disks, stones, and burs. By doing this he can decrease the unpleasant sequelae of vibration to their minimum, thereby reducing the patients' antagonism to operative procedures.

INSTRUMENT DESIGN

Instrument design must be considered from two aspects; first, the handpiece and contra-angle, and second, the revolving tool which will do the actual cutting.

In considering the first, we must realize that there are four factors of importance: (1) friction, (2) vibration, (3) excessive wear, and (4) care.[7, 27] It is up to the manufacturers to produce a satisfactory instrument minimizing the above-mentioned factors. In the last five years they have supplied such instruments with varying degrees of success. However, in order to determine what instrument to use, we must try to think of these four factors and to evaluate them in terms of selection of an instrument.

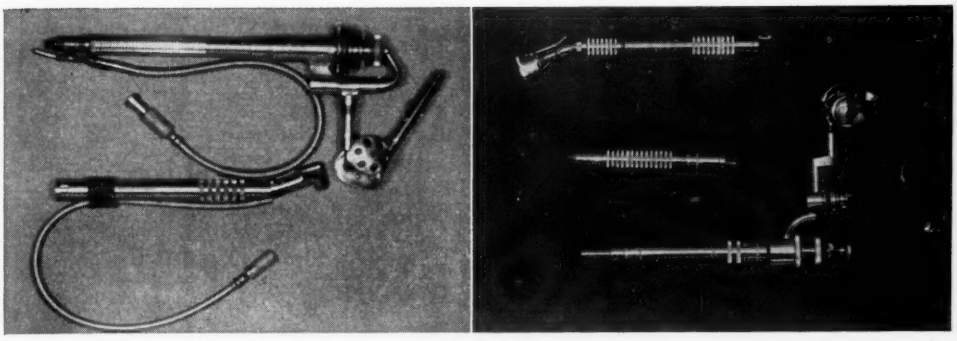
In medium high speed and high speed ranges, the factor of friction becomes important in that the handpiece and contra-angle that heat up beyond the tolerance of patient and dentist are unsuitable for this type of operation. If the handpiece has such features as ball bearing, needle bearing, and glass bearing in an attempt to reduce friction to its minimum, then we have an instrument that can be used for this speed of rotation. The instrument that requires a minimum of lubrication is the most ideal because it reduces the valuable time of the dentist and his assistant in relatively unnecessary work. (Overlubrication is one of the primary causes for overheating of the instrument.)

One of the most probable areas or sites of vibration has been where the junction of a conventional size contra-angle is attached to the sheath of the handpiece. At higher speeds, this source of vibration is reduced by the attachment of a long sheath contra-angle in place of the handpiece sheath, or by the placement of a long sheath contra-angle over the handpiece (Fig. 11). The construction of a contra-angle, being gear-driven, with ball-bearing or friction-bearing parts, requires utmost care to prevent overheating and excessive wear. Unfortunately, wear must take place with such gear-driven tools and, therefore, true running rotating tools should be used at all times. It is imperative to repair such wear as may take place in order to re-establish a smooth-running instrument.

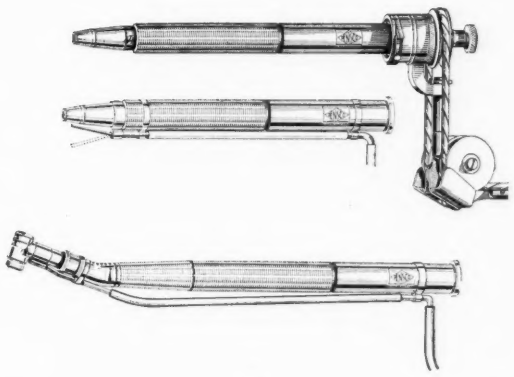
With turbine-driven instruments, such factors are reduced considerably by the elimination of gears, belts, and pulleys, and turbines would seem to be the answer to the ideal mechanism for higher speed operation. However, at present, it necessitates the placement of additional equipment in the operating room, the use of only a contra-angle, and the decreased torque that is an integral feature of such a piece of apparatus.

In the ultra high speed range, there is equipment that allows a bur or diamond stone to rotate relatively free from vibration, friction, and wear. The interesting feature of this equipment is that it requires little care since it is not gear driven but belt driven. However, this equipment is also contra-angled in design and not applicable to all restorative procedures (Fig. 12).[31, 32]

The second phase of instrument design pertains to the rotating tool itself. At medium high and high speeds, the two types of instruments used are the tungsten carbide and diamond tools. When tungsten carbide burs were first developed, they



A. *B.*



C.

Fig. 11.—Several types of high-speed equipment utilizing a long sheath contra-angle.

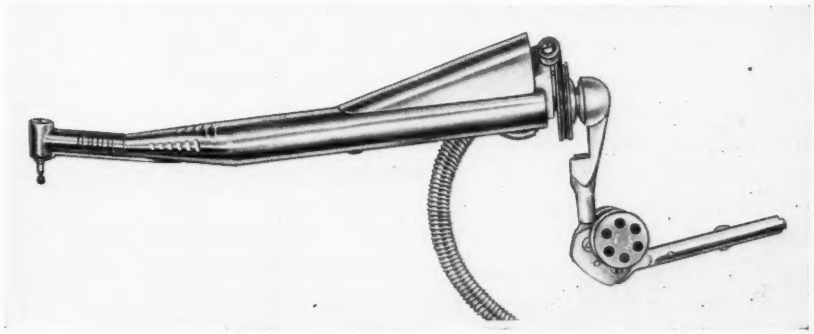


Fig. 12.—A type of ultra high speed handpiece.

presented an advantage over steel burs, particularly when faster speeds were used for their rotation. Research showed that not only will tungsten carbide burs remove more tooth structure faster per unit time, but also will remove it more efficiently from the standpoint of friction produced. This was one of the basic reasons for the interest and development of higher speeds. In response to an obvious need, equipment with the necessary devices for utilizing this new tool to its greatest advantage was made available.

It must be understood that the removal of tooth structure takes place by one of two methods; milling as with a bur or grinding as with a stone (Fig. 13). Early experiments have shown that a milling operation obtained its maximum efficiency at 12,000 r.p.m., and the removal of tooth structure did not increase proportionately to any further increase of r.p.m. It was then stated that the optimum speed for the use of a carbide bur was about 12,000 r.p.m., and higher speeds were not further effective.[9]

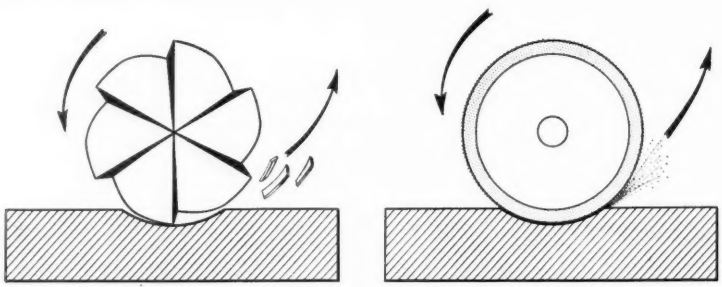


Fig. 13.—Removal of tooth structure takes place either by milling as with a bur or grinding as with a stone.

The original design of the carbide bur simulated the steel bur by having eight flutes, but further investigation showed that a six-fluted carbide bur was more efficient. On the other hand, grinding tools, such as diamond stones, increased their efficiency as the speed increased, and there was no limitation in the amount of tooth structure removed per unit time.[9]

When ultra high speeds are used, it has been observed clinically that despite this data, the milling tool in ranges over 100,000 r.p.m. seems to remove more tooth structure per unit time than was previously noted. This would seem to indicate that a re-evaluation of the effectiveness of the milling tool must be determined in the ultra high speed range. In line with this thought, it has also been observed clinically that the coarse diamond tool is more effective in removing tooth structure in that it seems to act as a milling tool instead of a grinding tool. It can then be stated that in ultra high speed ranges, carbide burs and coarse diamond stones should be used at this speed.

In the medium and high speed range, coarse diamond instruments are contraindicated because of the vibration. However, at ultra high speed, the coarse diamond stone does not have a deleterious effect from the vibration, since the vibratory perception of the patient is markedly diminished or eliminated. Therefore, carbide tools should be used in the 12,000 r.p.m. range, fine diamond stones should be

used in the high speed range up to 20,000 r.p.m., and coarse diamonds and carbide burs in the ultra high speed ranges of 100,000 r.p.m. or better for the most effective removal of tooth structure.

SELECTION OF CUTTING TOOLS

In the selection of carbide burs, the following features should be noted: (1) the fluting of the tool, (2) the rigidity of the shank, and (3) the trueness or eccentricity of the cutting tool. By reducing the fluting from the original eight to six flutes, the cut tooth structure is allowed to escape more readily, and thereby the efficiency of the cutting edges is increased. By having a thicker shank, whip is eliminated and vibration is reduced (Fig. 14). By having the shank made of vanadium, fracture of the bur at the junction of the shank and blade is markedly minimized.

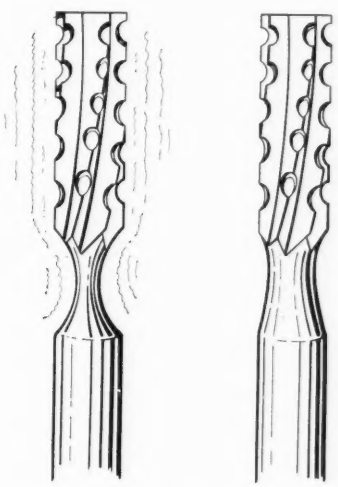


Fig. 14.—By increasing the thickness of the shank, whip and vibration are markedly reduced at higher speeds.

The selection of diamond tools demands other criteria. The following features should be considered: (1) a balanced shaft constructed so that there is no eccentric relationship to the wheel or cutting stone, (2) even distribution of diamond particles of uniform size of either fine or coarse grit, depending on the speed to be utilized, (3) symmetrical perforations to avoid unbalanced rotation which is a potential cause of whip or vibration, and (4) even uniform thickness of disks and stones (Fig. 15). The use of a mandrel-mounted diamond tool is definitely contraindicated since at higher speeds the whip developed by this type of mounting is a marked cause of vibration due to possibility of eccentric relationship.

PATIENT REACTION

In view of the preceding discussion, it is necessary to analyze the reaction of the patient to this newer concept of tooth-cutting. The factors that cause patient

apprehension will bear repetition at this point and consist primarily of heat production, vibrational sensation, length of the operating time needed, number of visits needed, and mental attitude toward restorative procedures. If, by utilization of medium high, high, and ultra high speed techniques, these causative factors can be diminished or eliminated, the subjective patient reaction to this concept of cavity preparation is more favorable and acceptable. Since the introduction of this higher speed procedure, it has been found by clinical observation and questioning that patients are more relaxed, more cooperative, less apprehensive, and less likely to cancel appointments.

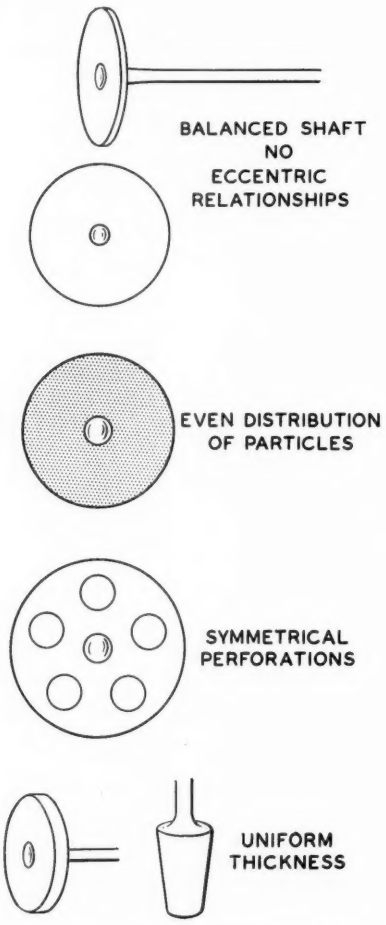


Fig. 15.—Criteria for the selection of grinding tools (diamonds).

OPERATOR FATIGUE

The major causes of operator fatigue in cavity preparations at conventional speeds are: (1) duration of operation, (2) vibration produced in handpiece, (3)

force needed to control rotary instrumentation, (4) apprehension on the part of the dentist about possibly producing traumatic injury due to loss of control of rotating disks and stones, and (5) lack of patient cooperation. However, apprehension and fatigue of the dentist are diminished because the force needed for higher speed techniques is reduced. This results in more digital control and less slippage and wedging of the rotating tool. This relaxation of the dentist is in turn transmitted to the patient, causing a more beneficial cycle to all concerned. In view of this, the dentist is then in a position to produce more work per unit of time or, if he prefers, to enjoy more leisure time.[7]

EFFICIENCY

Efficiency must be considered from varying points of view: (1) efficiency of the dentist producing better work more rapidly per unit of time, (2) mechanical efficiency as defined from a physical concept, and (3) the efficiency of the cutting tools at the varying speeds.[9, 17]

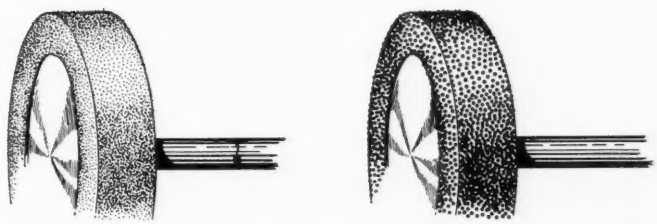


Fig. 16.—Size and dispersion of diamond grit varies as the speed. The greater the r.p.m., the larger the size and the wider the dispersion of the diamond grit.

Since the dentist is not limited by patient apprehension or his own fatigue, he is at liberty to produce more ideally conceived preparations in line with the concepts of better dentistry. In addition, in his original prescription for the patient, the dentist might conceive of more extensive restorations because of their relative ease of completion, thereby rendering a better service to his patient.

Mechanical efficiency is defined as work produced (tooth structure removed) as against friction developed. Since coolants are essential to high speed procedures, and since force is reduced, it has been shown by many investigators[8, 9, 20] that, at higher speeds, the incidence of friction is markedly reduced in relation to quantity of tooth structure removed. Thus, by definition, mechanical efficiency is greatly increased.

Cutting tools, such as carbides, have been shown to have increased efficiency up to 12,000 r.p.m. However, subsequent observation in the ultra high speed range, has shown that carbides cut tooth structure effectively, despite the disadvantages inherent at the intermediate speeds. Diamond tools on the other hand improve in efficiency with no apparent limitations. The diamond tool design should be altered to effect more removal of tooth structure by the use of larger particles of diamond grit and increased dispersion of the diamond grit on the diamond tool at the ultra high speed range (Fig. 16).

ECONOMICS

If any given procedure can be completed accurately and safely in less time, thereby increasing a dentist's productivity, then it must be economically sound. Undoubtedly, it would warrant any expenditure of effort on the part of the dentist to accomplish this result. A conversion to higher speeds is within the reach of anyone in the dental profession. It involves slight financial investment and little change in his established motor habits and concepts in cavity preparation. Although specialized instruction and techniques are not basically needed, the operator should be oriented in his selection of the proper equipment and cutting tools so that he may evaluate his own needs and select the equipment best suited for him.

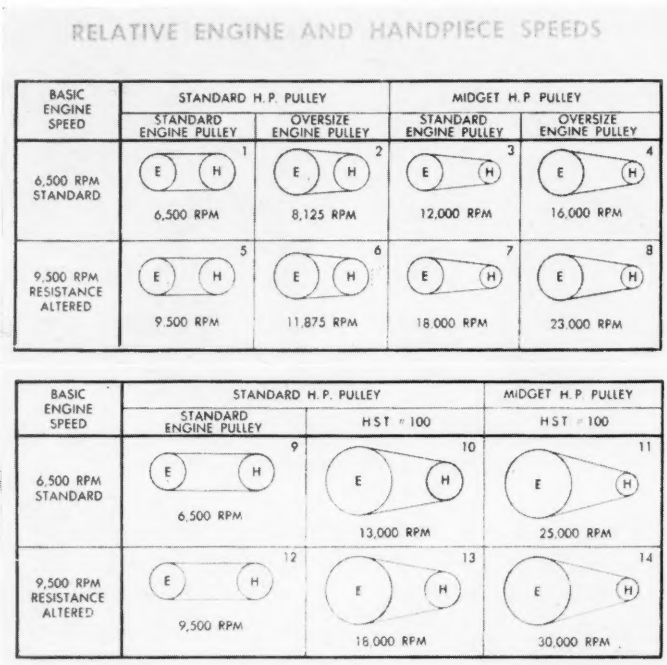


Fig. 17.—A means of increasing r.p.m. by alteration of pulley wheels and pulley ratios.

ADAPTABILITY OF STANDARD EQUIPMENT

Most of the dental equipment in use today can easily be modified to allow for higher speed techniques. The standard dental motor revolving at 3,000 to 6,000 r.p.m. can be increased to 8,000 to 15,000 r.p.m. by removing or changing the resistors in the unit. Varying types of high speed transmissions, which are simply pulley arrangements, are available for installation on the dental motor (Fig. 17). This will further increase the rotating speed of the tool. Any dental equipment company or dental equipment mechanic can accomplish these changes quickly and inexpensively. By judicious selection of a modern high speed dental handpiece, the rotary speed can be increased still further and, with proper maintenance, will deliver good service with little wear or vibration. Another means of increasing rotary speed

is to keep the belt slack. This can be determined by tightening or loosening the belt and gauging the pitch of the sound emanating from the equipment to determine the optimum rotational speed. Since coolants are a necessity, various devices exist to supply air, water spray, or a complete washed field technique as the dentist desires. Different types are available, ranging from the patient or assistant controlled method, to the automatic system controlled by the dentist. For complete visibility in operating, evacuating devices exist which complete this armamentarium for higher speed techniques.

PRACTICAL APPLICATION

These techniques are within the reach of every dentist. Conversion should be made to produce a reasonable degree of increased efficiency but remain within the practical limits of the particular dental office economy where it is instituted, and to comply with the personality and temperament of the individual dentist. There is very little change from the basic, accepted, and standardized concepts of operative procedures, but the slight modifications that may be necessary are possible for every practicing dentist.

SUMMARY

From the foregoing, it can be concluded that higher rotary instrumentation has many marked advantages. An individual with no high speed equipment or experience should absorb the principles involved in high-speed cutting by working in the medium and high speed ranges until he is fully indoctrinated with the factors involved in these procedures.

With this experience as a basis, and recognizing the factors of lessened operating forces, correct rotary instrument and equipment design, and the value of patient response to lessened vibration, heat, and rapidity of production, he then may ultimately progress into the ultra high speed ranges and enjoy the advantages inherent in this modality of tooth preparation.

DISCUSSION

It is apparent that in this era of electronic and atomic marvels and wizardry, the dental profession must keep abreast of these innovations. The development of higher speed techniques is a step forward in this direction. It depends upon those men who, by trial and experimentation, perfect the new techniques to submit their findings so that this progress can be accomplished. Every advancement in thought, technique, and procedure has its antagonist and protagonist, but higher speeds have evolved beyond the stage of experimentation and are now an accepted dental procedure in dental offices throughout the country. Whatever means for cutting tooth structure at higher speeds is developed, there is no doubt that in the ultra high speed ranges we have moved forward to the farthest advance from the point of view of the operator and the patient. Other operating techniques, such as ultrasonics, are also a step forward in the same direction, to create better dentistry, to create better patient education and cooperation, and to improve the working conditions of the dentist.

REFERENCES

1. Weinberger, B. W.: Introduction to the History of Dentistry, vol. 2, St. Louis, 1948, The C. V. Mosby Co.
2. Black, Robert B.: Technic for Nonmechanical Preparation of Cavities and Prophylaxis, J.A.D.A. **32**:955, 1945.
3. Morrison, A. H.: Operative Dentistry Department Manual of Airbrasive Technic, New York, 1951 (New York University College of Dentistry).
4. Epstein, S.: Analysis of Air Abrasive Procedures in Dental Practice, J.A.D.A., **45**:578, 1951.
5. Morrison, A. H., and Berman, Leonard: Evaluation of the Airdent Unit: Preliminary Report, J.A.D.A. **46**:298, 1953.
6. Henschel, Chester J.: The Friction of Revolving Steel Burs, J.A.D.A. **31**:895, 1944.
7. Ingraham, Rex, and Tanner, H. M.: Adaptation of Modern Instruments and Increased Operating Speeds to Restorative Procedures, J.A.D.A. **47**:311, 1953.
8. Hartley, J. L.: Study of Cutting Efficiency and Vibration Production of Diamond Abrasive Cutting Instruments (Abstract), J. D. Res. **32**:710, 1953.
9. Henry, E. E., and Peyton, F. A.: Study of the Relationship Between the Design and Cutting Efficiency of Dental Burs (Abstract), J. D. Res. **32**:709, 1953.
10. Catuna, M. C.: Sonic Energy: A Possible Dental Application. Preliminary Report of an Ultrasonic Cutting Method, Ann. Dent. **12**:100, 1953.
11. Oman, C. R., and Applebaum, Edmund: Ultrasonic Cavity Preparation. Preliminary Report, New York D. J. **20**:256, 1954.
12. Oman, C. R., and Applebaum, Edmund: Ultrasonic Cavity Preparation, II. Progress Report, J.A.D.A. **50**:414, 1955.
13. Nielsen, A. G., Richards, J. R., and Wolcott, R. B.: Ultrasonic Dental Cutting Instrument: I., J.A.D.A. **50**:392, 1955.
14. Zach, Leo, and Brown, G. N.: Pulpal Effect of Ultrasonic Cavity Preparation, Preliminary Report, New York D. J. **22**:9, 1956.
15. Zach, Leo, Morrison, Arthur H., and Cohen, Gerson: Thermogenetic Effect of Ultrasonic Cavity Preparation, New York D. J. **23**:123, 1957.
16. McEwen, R. A.: Accelerated Handpiece Speeds in Restorative Dentistry (Progress Report), New York D. J. **20**:250, 1954.
17. Walsh, J. P., and Symmons, H. F.: Comparison of the Heat Production and Mechanical Efficiency of Diamond Instruments, Stones, and Burs at 3,000 and 60,000 r.p.m., New Zealand D. J. **45**:28, 1949.
18. Vaughn, R. C., and Peyton, F. A.: Influence of Rotational Speed on Temperature Rise During Cavity Preparation, J. D. Res. **30**:737, 1951.
19. Peyton, F. A.: Temperature Rise and Cutting Efficiency of Rotating Instruments, New York D. J. **18**:439, 1952.
20. Hudson, Donald C., and Sweeney, W. T.: Temperatures Developed in Rotating Dental Cutting Instruments, J.A.D.A. **48**:127, 1954.
21. Jesserich, P. H.: Factors Necessary to Minimize Thermal Changes in Tooth Structures from Operative Procedures. Abstract. New York D. J. **25**:275, 1935.
22. Editorial: Acceptability of New Dental Operative Devices, New York J. Den. **25**:376, 1955.
23. Seldin, Jules: Speed in Dentistry (Editorial), New York J. Den. **25**:3, 1955.
24. Peyton, F. A., and Henry, E. E.: Problems of Cavity Preparation With Modern Instruments, New York J. Den. **22**:147, 1952.
25. Henry, E. E., and Peyton, F. A.: Vibration Characteristics of the Rotating Dental Instrument, J. D. Res. **29**:601, 1950.
26. Nelsen, Robert J., Pelander, Carl E., and Kumpula, John W.: Hydraulic Turbine Contra-angle Handpiece, J.A.D.A. **47**:324, 1953.
27. Peyton, F. A.: Evaluation of Dental Handpieces for High Speed Operations, J.A.D.A. **50**:383, 1955.
28. Hudson, D. C., Hartley, J. L., Moore, Robert, and Sweeney, W. T.: Factors Influencing the Cutting Characteristics of Rotating Dental Instruments, J.A.D.A. **50**:377, 1955.
29. Walsh, J. P. and Symmons, H. F.: Vibration Perception and Frequencies, New Zealand D. J. **45**:106, 1949.
30. Houssoy, B. A.: Human Physiology, ed. 2, New York, 1955, McGraw-Hill Book Co., Inc.
31. McEwen, R. A.: Use of Rotary Instruments at Ultra High Speeds, J. Georgia D.A. **29**:10, 1956.
32. Kilpatrick, H. C.: Trauma Reduction in Cavity Preparations Utilizing Rotational Speeds in Excess of 60,000 R.P.M., D. Digest **62**:202, 1956.

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PULP RESPONSE TO CAVITY PREPARATION

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THE PROGENITOR OF ALL ROTARY instruments was the hand awl. About 90 years ago, the air-driven Green and the foot-propelled Morrison dental engines were introduced. At the time, concern for their safeness was expressed.[1] About 20 years later, Kells developed the electric dental engine. Once again, the profession inquired into the possible dangerous consequences of its use.[2] More recently, the pulpal response to instrumentation satisfied the urgent need of evaluating potential injury.[3-14]

The current advances in rotational equipment have greatly exceeded the pace of pulp response investigation. For many years, rotational speeds of approximately 5,000 revolutions per minute were standard. High and super speeds, ranging from 12,000 to 200,000 revolutions per minute now have been introduced. At the same time, diamond points and carbide burs have become supplements to carborundum points and steel burs.

After two years of developmental investigation, a gas-impelled abrasive was successfully utilized to prepare cavities in teeth.[15] This marked the first departure from the conventional rotary technique. A second innovation in dentistry was the introduction of an ultrasonic device for cavity preparation.[16]

This report is concerned with the pulp response to rotary instruments, airbrasive, and ultrasonics on teeth of limited growth in dogs and human beings. The results establish that, correctly used, the methods tested induced minimal, if any, injury and that speeds as high as 24,000 r.p.m. with water coolant, airbrasive, and ultrasonic techniques meet the standard of safety already established by low-speed rotational technique.

MATERIALS AND METHODS

Two hundred forty-nine cavities were prepared in sound teeth of dogs and human beings. The cavities were prepared to the optimum depth of 0.5 to 1.0 mm. pulpal to the dentino-enamel junction.[17] All cavities were prepared to include

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the entire width of the buccal or labial surfaces of the teeth. The preparations were approximately 2 mm. wide and from 2 to 13 mm. long in the gingival third of the teeth. Four methods of cavity preparation were utilized. These included airbrasive, ultrasonics, and rotary instruments at two speeds.

All animals were anesthetized with Nembutal. Human beings received local anesthetics as required. Most of the cavities prepared with rotary instruments in human subjects were effected under local anesthesia. Airbrasive and ultrasonic preparations were completed without the use of local anesthesia. All cavities were restored with a nonirritating zinc oxide and eugenol cement after expressing the excess eugenol.

Specimens were taken at 1, 7, and 28 days. All human teeth were either anteriors to be sacrificed for prosthetic purposes or bicuspids removed for orthodontic therapy. The extractions were effected by inserting an elevator buccally or labially and lingually to the teeth so that the forcep could be applied as far apically as possible in order to avoid the possibility of aspirating odontoblasts into the dentin.[18] The dog teeth were removed by resection.

To achieve adequate fixation, the proximal surfaces of all teeth were removed with a diamond saw under a water coolant. The specimens were fixed in 10 per cent formalin, decalcified, sectioned, and stained with hematoxylin and eosin.

CRITERIA OF INJURY

In order to evaluate the degree of injury to the pulp as a result of cavity preparation, several readily recognized criteria were used. Cytoplasmic deterioration, recognized as homogeneity and loss of reticular appearance, may occur without nuclear changes. Cellular death is generally recognized by karyorrhexis, karyolysis, or pyknosis. Cellular death, vesicle formation, and displacement of odontoblasts into the dentin are all evidence of excessive thermogenesis.[19] The presence of these histologic entities establishes that the pulp has been injured. The presence of inflammatory cells in addition to the vascular changes of inflammation is the general yardstick used to determine response to injury. Changes such as vacuoles and reticular atrophy generally are post-mortem phenomena caused by inadequate fixation.[19]

Moderate injury to dentin produces a pulp response in the region of the affected tubules.[20] The odontoblasts and subjacent stroma respond. The vascular changes may be more widespread. However, since the injury is localized, the odontoblasts communicating with uninjured dentin may be considered as regions of control tissue. Thus it is possible to establish a control region for each specimen and to eliminate subtle changes caused by the difficulties of fixation which affect the entire pulp. Only in cases of severe injury, where irreversible and readily recognized changes occur, does the extent of injury exceed the area of injured tubules, and then progressive degeneration occurs.

LOW SPEED

For many years, the intermittent application of rotary instruments for cavity preparation at 5,000 r.p.m. has been a standard procedure. Seventeen cavities were

prepared in one human and 16 dog teeth by this method. A No. 37 steel bur was used to penetrate the enamel. It was applied to the tooth intermittently for one second and removed for one second to permit cooling of the tooth and bur. After establishing the outline, resistance, and retention forms, a new 558 steel bur, applied in the same manner, was used to extend the preparation and complete the roughed-out cavity form.

Histologic examination revealed that, in all cases, the pulp showed no injury as defined by established criteria. Figs. 1 through 6 illustrate the effect of low-speed intermittent cavity preparation. Twenty-four hours after cavity preparation (Fig. 1), the pulp appears histologically normal, the odontoblasts at the pulpal ends of the cavity being histologically similar to those in the control region. Under higher magnification (Fig. 2), the predentin, odontoblasts, and vascular bed appear normal, and there is no evidence of inflammation. Fibroblastic proliferation in the layer of Weil indicates stimulation rather than irritation. One week after cavity preparation (Figs. 3 and 4), the same histologic lack of evidence of injury may be seen. One month after cavity preparation (Figs. 5 and 6), there was no evidence of inflammation or of repair, the latter generally being manifested by secondary dentin formation. Figs. 1 to 6 illustrate the lack of response to low-speed intermittent cavity preparation. The pulps are histologically normal when examined at 1, 7, and 28 days.

Since removal of sound tissue is necessary to restore crowns of teeth, and since an intermittently applied low-speed technique has been successfully used for 100 years, it has become an acceptable standard and is used in this investigation as a control.

HIGH SPEED

In this study, a rotational speed of 24,000 was the standard used to test high speed. Seventy cavities were prepared in 58 dogs and 12 human teeth under a continuous water stream. The initial opening into the dentin was made with a wheel-shaped diamond point 4 mm. in diameter and 0.5 mm. thick. The diamond point was applied to the tissue continuously until it had served its function. The same instrument was used for ten preparations before it was discarded. A new 558 steel bur was then used to rough out the cavity with continuous application under a water coolant.

Figs. 7 to 12 illustrate the results of cavity preparation under the described conditions. The optimum depth of cavity preparation may be seen in Figs. 7, 9, and 11. No evidence of localized injury is evident. The findings are similar to those at low-speed intermittent cavity preparation. Displaced odontoblasts and vesicles, evident immediately after thermogenic cavity preparation,[19] are not seen.

AIRBRASIVE

Cavity preparation by airbrasive techniques presents a new and different type of energy used for this purpose. It may be described as the kinetic energy of a high-velocity stream of microscopic abrasive particles. It is a nonthermogenic technique which actually causes a 5 degree reduction in temperature.

Seventy-nine cavities were prepared in 16 human and 63 dog teeth. The cavity dimensions were approximately the same as those described for rotary instruments.

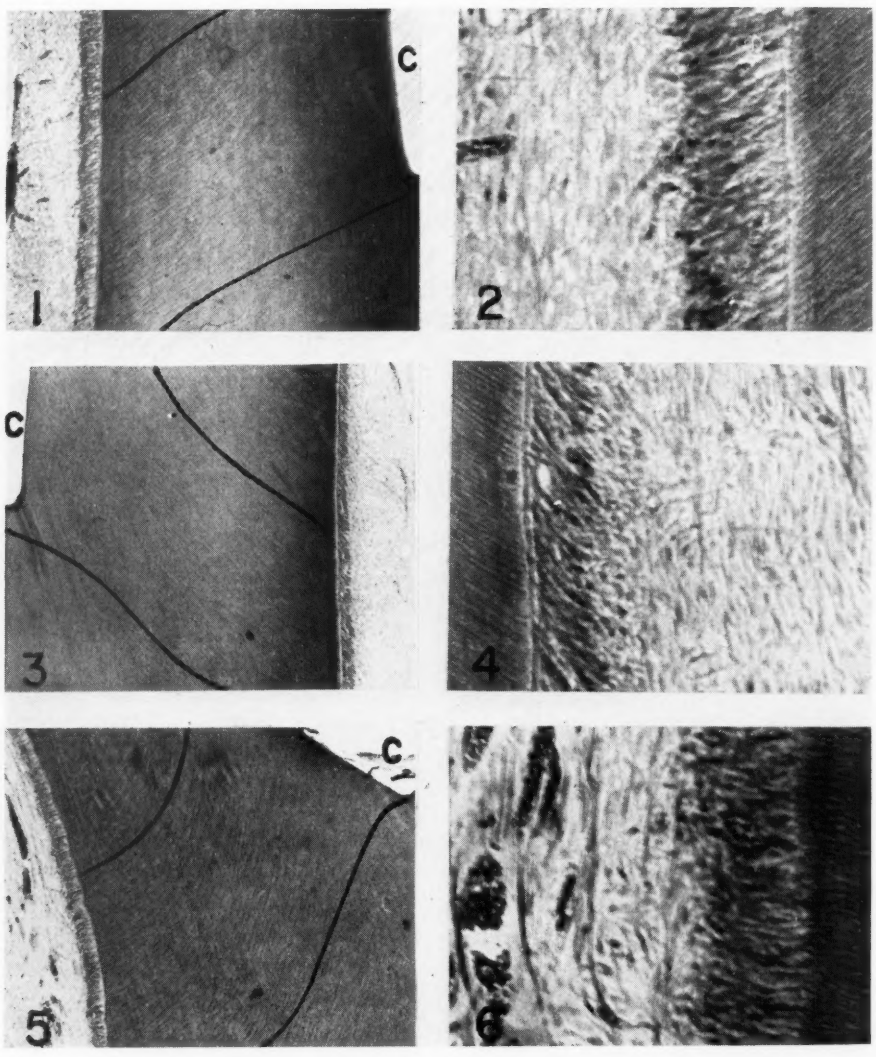

Fig. 1.—Photomicrograph of a one-day specimen of an intermittent low-speed cavity preparation (*C*). The area of cut tubules is outlined. The thickness of the dentin from the cavity preparation to the pulp is 1.3 mm. (Mag. X35.)

Fig. 2.—Higher magnification of the area of cut tubules from Fig. 1. (Mag. X200.)

Fig. 3.—Photomicrograph of a 7-day specimen of an intermittent low-speed cavity preparation (*C*). The area of cut tubules is outlined. The thickness of dentin from the cavity preparation to the pulp is 1.4 mm. (Mag. X35.)

Fig. 4.—Higher magnification of the area of cut tubules from Fig. 3. (Mag. X200.)

Fig. 5.—Photomicrograph of a 28-day specimen of an intermittent low-speed cavity preparation (*C*). The area of cut tubules is outlined. The thickness of dentin from the cavity preparation to the pulp is 1.1 mm. (Mag. X39.)

Fig. 6.—Higher magnification of the area of the cut tubules from Fig. 5. (Mag. X200.)

Figs. 13 to 18 illustrate the pulp response to optimum depth cavity preparation by airbrasive technique. Evidence of localized injury is again completely

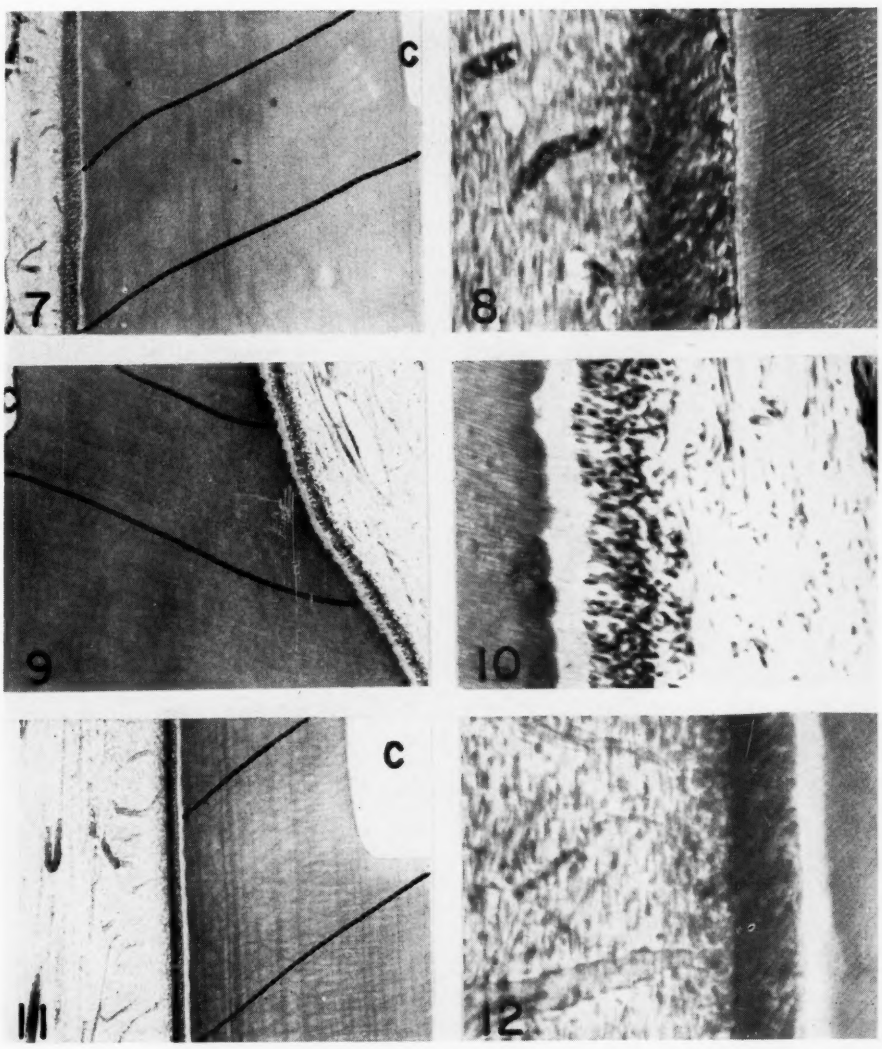

Fig. 7.—Photomicrograph of a one-day specimen of a high-speed cavity preparation (*C*), with water coolant. The area of cut tubules is outlined. The thickness of dentin from the cavity preparation to the pulp is 1.4 mm. (Mag. X35.)

Fig. 8.—Higher magnification of the area of the cut tubules from Fig. 7. (Mag. X200.)

Fig. 9.—Photomicrograph of a 7-day specimen of a high-speed cavity preparation (*C*), with water coolant. The area of cut tubules is outlined. The thickness of dentin from the cavity preparation to the pulp is 1.1 mm. (Mag. X35.)

Fig. 10.—Higher magnification of the area of the cut tubules from Fig. 9. (Mag. X200.)

Fig. 11.—Photomicrograph of a 28-day specimen of a high-speed cavity preparation (*C*), with water coolant. The area of cut tubules is outlined. The thickness of dentin from the cavity preparation to the pulp is 0.8 mm. (Mag. X35.)

Fig. 12.—Higher magnification of the area of the cut tubules from Fig. 11. (Mag. X200.)

lacking. Under higher magnification (Figs. 14, 16, and 18) the pulp cells and vascular system are normal. The odontoblasts showed no cytologic changes as-

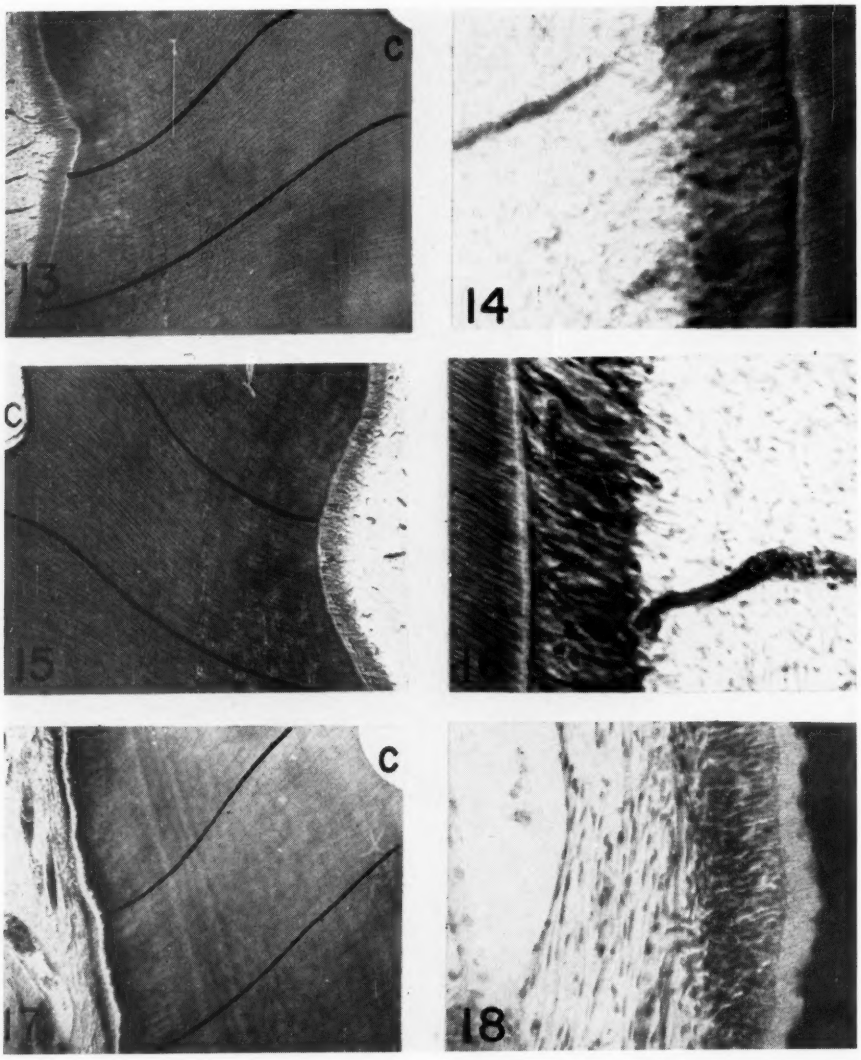

Fig. 13.—Photomicrograph of a 1-day specimen of an airbrasive cavity preparation (*C*). The area of cut tubules is outlined. The thickness of dentin from the cavity preparation to the pulp is 1.7 mm. (Mag. X30.)

Fig. 14.—Higher magnification of the area of the cut tubules from Fig. 13. (Mag. X200)

Fig. 15.—Photomicrograph of a 7-day specimen of an airbrasive cavity preparation (*C*). The area of cut tubules is outlined. The thickness of dentin from the cavity preparation to the pulp is 1.3 mm. (Mag. X35.)

Fig. 16.—Higher magnification of the area of the cut tubules from Fig. 15. (Mag. X200.)

Fig. 17.—Photomicrograph of a 28-day specimen of an airbrasive cavity preparation (*C*). The area of cut tubules is outlined. The thickness of dentin from the cavity preparation to the pulp is 1.1 mm. (Mag. X35.)

Fig. 18.—Higher magnification of the area of the cut tubules from Fig. 17. (Mag. X200.)

sociated with degeneration. No secondary dentin formed one month after cavity preparation.

ULTRASONICS

The introduction of ultrasonic technique for cavity preparation presented a third type of energy used for cavity preparation. It is effected by a rapidly vibrating instrument in the presence of a slurry consisting of water, air, and abrasive particles similar to those used in the airbrasive technique. Extensive investigation of its effect has already been reported.[21-28]

Eighty-three cavities were prepared in 12 human and 71 dog teeth. Cavity dimensions were approximately the same as those executed for the other experiments.

Photomicrographs (Figs. 19 to 24) illustrate the depth of cavity preparation and the localized region of the pulp bounded by the severed odontoblastic processes. No evidence of injury is seen under higher magnification. Examination of the odontoblasts, stroma, and vascular system of the pulp in the circumscribed area of the severed tubules showed normal pulp elements, and the similarity of pulp response to other techniques of cavity preparation is noteworthy.

DISCUSSION

In this investigation, every effort was made to simulate known requirements for ideal cavity preparation. Controlled laboratory methods for depth of cavity and load were not attempted. In the final analysis, these factors are not available to the clinician. Controlled laboratory techniques are evaluated for the clinician who, in turn, can only rely on the human effort to duplicate the results. The depth of cavity preparation and the load applied to rotary and ultrasonic instruments are achieved by tactile or visual perception. Other factors, such as rotational speed, instrument size, and continuous and intermittent application, can be measured by the operator.

It is inconceivable that cavity preparation in sound teeth does not cause any injury to the pulp. Partial amputation of hundreds of thousands of odontoblastic processes must be regarded as injurious. It is the degree of injury that is significant. Subtle changes, such as the appearance of vacuoles and granules in the cytoplasm, which are frequently described as evidence of injury, are questionable as measurements of injury, since controls for these alterations are not in evidence. Both vacuoles and granules are accepted as normal components of cells. Cell changes, evident in cytomorphosis, must be standardized before such subtle changes associated with injury may be acceptable for evaluation of operative procedures.

In this study, the peripheral ends of odontoblastic processes were amputated 0.5 to 1.0 mm. This is a standard depth for intracoronal preparations and has been recommended as the procedure which minimizes injury.

Cavity depth is not the only factor to cause injury. Optimum depth with thermogenic preparation will cause severe injury.[19] Injury of the pulp may be caused by caries, erosion, abrasion, attrition, and even systemically by long-standing disease or radioactive isotopes. Salivary contamination of dentin, medications, and some restorative materials are local offenders.

The optimum depth of cavity preparation must be accepted as a standard in the evaluation of pulp response to cavity preparation. Cavities prepared closer to the pulp than the optimum must be construed as evidence of injury caused by depth

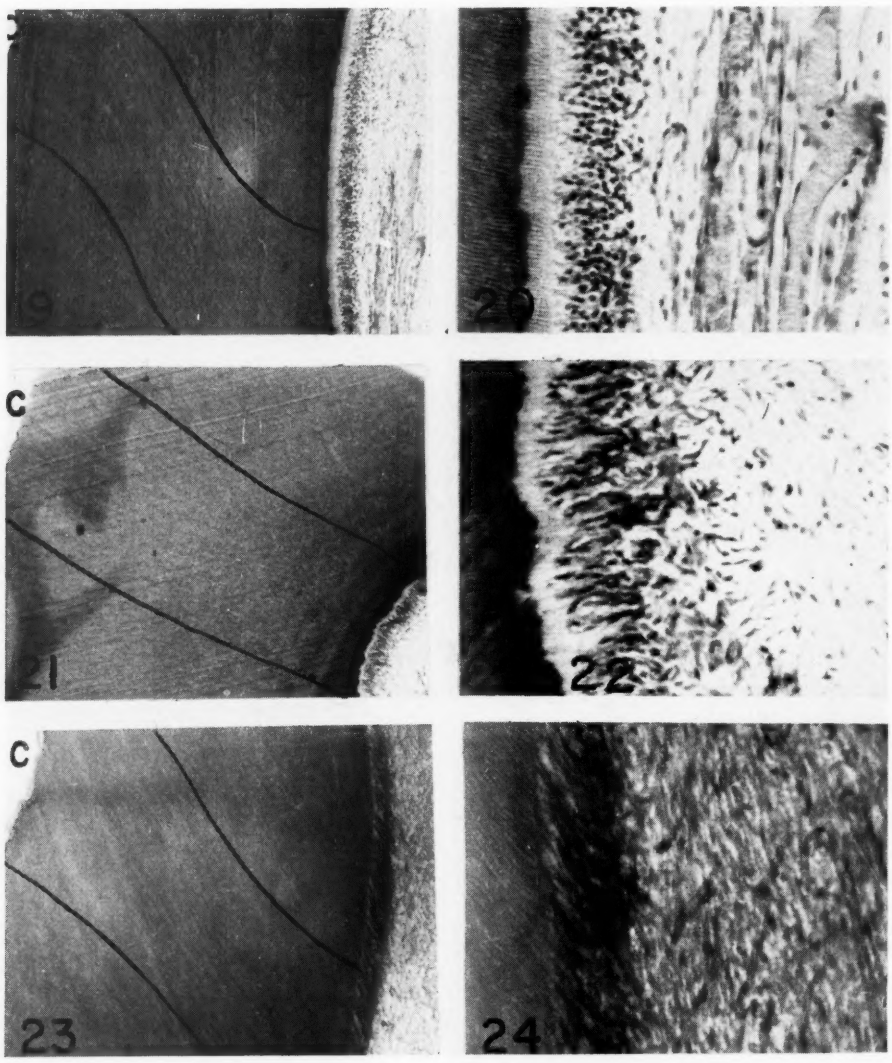

Fig. 19.—Photomicrograph of a 1-day specimen of an ultrasonic cavity preparation (*C*). The area of cut tubules is outlined. The thickness of dentin from the cavity preparation to the pulp is 1.3 mm. (Mag. X35.)

Fig. 20.—Higher magnification of the area of the cut tubules from Fig. 19. (Mag. X200.)

Fig. 21.—Photomicrograph of a 7-day specimen of an ultrasonic cavity preparation (*C*). The area of cut tubules is outlined. The thickness of dentin from the cavity preparation to the pulp is 1.8 mm. (Mag. X28.)

Fig. 22.—Higher magnification of the area of the cut tubules from Fig. 21. (Mag. X200.)

Fig. 23.—Photomicrograph of a 28-day specimen of an ultrasonic cavity preparation (*C*). The area of cut tubules is outlined. The thickness of dentin from cavity preparation to the pulp is 1.0 mm. (Mag. X53.)

Fig. 24.—Higher magnification of the area of the cut tubules from Fig. 21. (Mag. X200.)

of preparation, and not the effect of instrumentation alone. The restoration of the experimental cavities with zinc oxide and eugenol cement eliminated chemical injury, especially from salivary contamination. None of the techniques used in this investigation exhibited histologic evidence of excessive temperature rise.

In the absence of caries, temperature rise, and chemical injury, only traumatic injury remains to be investigated. The findings in the study establish that traumatic injury to the pulp is minimal and reversible when the optimum cavity depth and thermogenesis are respected.

Similar results, measured experimentally, with 24,000 revolutions per minute using a water coolant, airbrasive, and ultrasonics under the same conditions place these three methods in the same category of safety as the time-honored low-speed technique. The pulp tissue appears as highly resistant to necessary insults of operative procedures rather than as the delicate cellular structure that has been suggested on the basis of philosophy rather than active investigation.

SUMMARY

Four methods of cavity preparation were tested for evidence of pulp injury. Specimens were taken at 1, 7, and 28 days. Examination of the pulps established that the techniques described were safe as measured by accepted standards. Dry intermittent application of rotary instruments at 5,000 r.p.m., continuous application at 24,000 r.p.m., with a water stream coolant, airbrasive, and ultrasonic techniques are biologically acceptable methods as measured by pulpal response.

REFERENCES

1. Kells, C. E.: Three Score and Nine, New Orleans, 1926, C. E. Kells, p. 12.
2. Kells, C. E.: Three Score and Nine, New Orleans, 1926, C. E. Kells, p. 145.
3. Palazzi, S.: Über die anatomischen veränderungen der zahnpulpa in folge von silikatzement füllengen, Ztschr. Stomatol, **21**:279, 1923.
4. Fasoli, G.: Silikatzement u. pulpaveränderungen, Ztschr. Stomatol, **22**:225, 1924.
5. Fish, E. W.: Reaction of the Dental Pulp to Peripheral Injury of Dentin, Proc. Roy. Soc. Med. **24**:108, 1931.
6. Gurley, W. B., and Van Huysen, G.: Histologic Response of the Teeth of Dogs to Operative Procedures, J. D. Res. **19**:179, 1940.
7. Manley, E. B.: Pulp Reactions to Dental Cements, Proc. Roy. Soc. Med. **36**:488, 1943.
8. Shroff, F. R.: Effects of Filling Materials on the Dental Pulp: An Experimental Study With Special Reference to Synthetic Porcelain, New Zealand D. J. **42**:99 and 145, 1946.
9. Rovelstad, G. H., and St. John, W. E.: Condition of the Young Dental Pulp After the Application of Sodium Fluoride to Freshly Cut Dentin, J.A.D.A. **39**:670, 1949.
10. Zander, H. A., Glenn, J. F., and Nelson, C. A.: Pulp Protection in Restorative Dentistry, J.A.D.A. **41**:563 1950.
11. Seelig, A., and Lefkowitz, W.: Pulp Response to Filling Materials, New York D.J. **16**:540, 1950.
12. Kramer, I. R. H., and McLean, J. W.: The Response of the Human Pulp to Self-polymerizing Acrylic Restorations, Brit. D. J. **92**:255 and 281, 1952.
13. James, V. E., Schour, I., and Spence, J. M.: Response of Human Pulp to Gutta-percha and Cavity Preparation, J.A.D.A. **49**:639, 1954.
14. Perreault, J. G., Massler, M., and Schour, I.: Reaction of Odontoblasts to Medicaments Placed in Cavity Preparations in Rat Incisors, J.A.D.A. **52**:533, 1956.
15. Postle, H. H.: Dental Clinics of North America, Philadelphia, 1957, W. B. Saunders Co. p. 43.
16. Lefkowitz, W.: Dental Clinics of North America, Philadelphia, 1957, W. B. Saunders Co. p. 53.

17. Oman, C. R.: An Operative Dentistry Syllabus, New York, 1948, Columbia University Press.
18. Orban, B.: Odontoblasts in the Dental Tubuli, J. D. Res. **20**:553, 1941.
19. Lefkowitz, W., Robinson, H. B. G., and Postle, H. H.: Interpretation of Histologic Sections of Pulp, Ohio State D. J. **31**:24, 1957.
20. Manley, E. B.: Experimental Investigation into the Early Effects of Various Filling Materials on the Human Pulp, Proc. Roy. Soc. Med. **34**:57, 1941.
21. Oman, C. R., and Applebaum, E.: Ultrasonic Cavity Preparation. Preliminary Report, New York D. J. **20**:256, 1954.
22. Zach, L., and Brown, G. N.: Pulpal Effect of Ultrasonic Cavity Preparation. Preliminary Report, New York D. J. **22**:9, 1956.
23. Butt, B. C., Harris, N. O., Shannon, I., and Zander, H. A.: Histopathologic Evaluation of Pulpal Response to Ultrasonic Cavity Preparation, I.A.D.R. Preprinted Abstracts No. 34, 1956.
24. Friedman, J., Lite, T., and Solomon, H.: Pulp Reactions to Ultrasonic Tooth Preparation, New York D. J. **26**:144, 1956.
25. Healey, H. J., Patterson, S. S., and Van Huysen, G.: Pulp Reaction to Ultrasonic Cavity Preparation. Preliminary Report, U. S. Armed Forces M. J. **7**:685, 1956.
26. Zach, L., Morrison, A. H., and Cohen, G.: Thermogenetic Effect of Ultrasonic Cavity Preparation, New York D. J. **23**:123, 1957.
27. Robinson, H. B. G.: Pulpal Effects of Operative Dentistry, J. Pros. Den. **7**:282, 1957.
28. Zach, L., Morrison, A. H., and Cohen, G.: Effects of Ultrasonic Operative Procedures on Developing Dentition, I.A.D.R. Preprinted Abstracts No. 185, 1957.

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STRATEGIC ENDODONTICS

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ROOT CANAL THERAPY, long a favorite whipping boy of both dentistry and medicine, has come of age as a safe, sound, scientific, and sometimes priceless aid to restorative dentistry.

Although Hunter[1] did not specify the pulpless tooth as a source in systemic disturbances, Billings,[2] Rosenow,[3] and others succeeded in making it a generally accepted etiologic factor in practically every disease of the human body. Their pronouncements happened to coincide roughly with the advent of dental roentgenography, which made it possible to visualize the results of the lamentably poor root canal work which had been generally accomplished prior to this time. An apical shadow was almost universally diagnosed as an infection or cyst, a diagnostic error which persists in many minds to this day, and the mass extraction era was launched.

The focal infection theory was enthusiastically embraced by dental and medical men alike, to the extent that there were few dissenters. The vast majority of dentists simply charged the pulpless tooth off as a bad bet, and few were willing to have a root canal treatment on their consciences in the honest belief that such an operation was prejudicial to the health of the patient. Teeth, of course, were not the only items of anatomy upon which the evil eye of focal infection was directed. At the height of this enthusiasm, Miller[4] was moved to remark, "If this unholy practice continues we shall wind up a witless, toothless, glandless, gutless, godless race." Throughout this endodontic drought, however, there were a number of open-minded men of scientific curiosity who were able to separate fact from theory, to bring endodontic procedures through the caldron of refinement, and place it upon the plane of useful service that it rightly deserves.

The preservation of the pulp and the problems presented by its loss constitute an inescapable factor common to every dentist. The castigation and vilification which were heaped upon the practice of root canal therapy from about 1920 to 1940 have resulted in a refining process of study and accomplishment, which places us in the position of either accepting the carefully and properly treated pulpless tooth as a safe and valuable service or hiding behind an honest or prejudicial ignorance of the subject.

Since the frightening aspect of the pulpless tooth is based upon its capacity to produce pathogenic organisms and feed them into the blood stream to set up a various assortment of systemic disturbances, it may be well to point out the fact that the research which led to these conclusions was founded upon recovery of organisms from the *roots* of *extracted* teeth, and not from the root canals. It has

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been proved that cultures obtained from the roots of extracted teeth have no significance.[5] Actually, and ironically, identical results could have been produced by simply culturing the saliva. The source of a focus of infection in a pulpless tooth lies *within* the canal, and there only.

Grossman[6] said, "It is a disconcerting statement to make but practically every investigation dealing with the pulpless tooth made prior to the studies of Fish and MacLean in 1936 is invalid." He further states, "More recently, the work of Fish and MacLean, Okell and Elliot, Burket and Burn, and Gunter and Appleton practically compel one to scrap all previous bacteriologic studies dealing with pulpless teeth."

The presence of bacteria does not necessarily indicate the presence of infection, and the presence of a rarefied area over the apex of a tooth cannot be identified roentgenographically as an infection. These areas are the tissue response to the process of inflammation from toxic irritants within the canal which may or may not also contain bacteria. A high percentage of canals which have lost apical bone are sterile. Conversely, many pulpless teeth without rarefied apical areas are found to harbor pathogenic organisms.

With or without bacteria, the content of the canal of an untreated pulpless tooth can be a source of potent toxicity due to the protein degradation of the organic matter of the pulpal tissue. Therefore, the pulpless tooth must be either treated or extracted. In any event, the dark areas we see in the roentgenographs are the natural defensive mechanisms at work which actually consist of a granuloma immediately adjacent to the root end surrounded by granulation tissue between the granuloma and the bone. The granuloma is a defense setup made up of leukocytes, lymphocytes, histocytes, and plasma cells, whereas granulation tissue is strictly a repair tissue made up of young fibroblasts, young capillaries, and inflammatory cells.[7]

ENDODONTIC TREATMENT

In brief then, the crux of endodontic treatment is to remove completely the contents of the root canal, enlarge it, and, after positive bacteriologic checks which are quite simple to accomplish, fill the canal with a tight hermetic apical seal with a substance of known tissue tolerance; then thoroughly obturate the remainder of the canal by forceful lateral condensation, thereby inducing a situation in which Nature has a free hand to repair the damaged apical tissue. This she will do rapidly and dramatically. It is hardly necessary to note that this be performed under immaculate asepsis. The technique is unique in that in no other surgical procedure known to the writer is it possible to check routinely, and with great accuracy, both the field of operation and the operating procedure for the presence of *any* bacteria, pathologic or nonpathologic. This has proved to be a strong point of argument with some of the medical men upon occasion. As for residual apical infection, Hedman[8] has shown that once the canal is sterile the apical area outside the canal is also sterile, irrespective of the condition of the tissue. Failure to heal or occurrence or recurrence of apical areas, following conservative treatment is due primarily to failure to obturate completely the canal with a very tight seal.[9, 10] The most perfect cleansing and sterilizing job is defeated if this is not accomplished. An underfilled canal with a good seal may be successful, whereas one filled to the exact apex with

a faulty seal may fail, although roentgenographically, the operation may appear excellent.* Neither apical curettage, nor root resection can be depended upon to compensate for this basic failure. It is interesting to note that an almost identical principle is involved in the treatment of periodontal lesions, wherein failure to remove the source of irritation completely will result in ultimate treatment failure regardless of the technique employed.

DRUGS

Drugs used for cleansing and sterilizing the canal should be confined to those of noncaustic, nonirritating properties, since they play a purely secondary role to the all-important principles of thorough nontraumatic cleansing of the canal in association with an aseptic operating technique. Sodium hypochlorite for cleansing and paramonochlorophenol for sterilization are adequate in most cases. Grossman has reported accelerated results by the use of a polyantibiotic paste.[11]

DIAGNOSIS

Endodontics has a definite and useful place. It is now enjoying an approval which will endure only if viewed and handled from a purely objective standpoint. It should be used for what it is worth on teeth and in mouths which are worthy of it. No treatment procedure can ever be 100 per cent effective either in application or success. Overenthusiasm and promiscuity must always be carefully restrained. No miraculous drug or refinement in technique can ever replace a careful and thoughtful diagnosis. Not every pulpless tooth can or should be treated, but many, many useful teeth can be maintained in a state of health and function by an intelligent program of root canal therapy. Too many of us are inclined to condemn the whole philosophy by observation of an isolated failure. Endodontic failures stem from the same principal causes which produce failures in other dental operations, namely, a faulty diagnosis, a job not done quite well enough, or both. Fortunately, we are allowed about the same tolerance of deviation from perfection in endodontics as in other procedures.

Regardless of the degree of mechanical skill one may possess, the life or death of the pulp is a problem common to every dentist. We restore many doubtful teeth and have to assume many risks. We make every effort to preserve the pulp, but we cannot afford to extract every tooth in which there is an element of risk. Paradoxically, an active interest in endodontics is invariably accompanied by a better understanding and appreciation of the vital pulp and its preservation. Today a great deal of "heavy" dentistry is being accomplished with much emphasis upon reconstruction and rehabilitation. This is well and good when performed by one who thoroughly understands what he is doing; but by many, this is done as a primarily mechanical process, and overemphasis upon the mechanical aspect of dentistry will inevitably and inescapably bring the dentist face to face with the basic biologic sciences.

There are many situations in which retention of a pulpless tooth represents the difference between a simple and satisfactory restorative procedure, and a com-

*A precise technique, developed by Dr. Ralph Sommer, for accomplishing the desired results without fear of forcing filling material through the apex is detailed in a book of recent publication.[5]

plicated one of dubious adequacy and/or esthetics. It can be the difference between a complete denture and an arch with serviceable natural teeth. The loss of a pulp can inject serious complications into a restorative case previously completed. It is, therefore, comforting to know that many of these strategic teeth may be retained in the mouth in a state of health, comfort, and serviceability, with a scientifically sound philosophy and without apology. While it is true that the mass extraction era has long since run its course, still today many useful and strategic teeth are being needlessly sacrificed.

THE PULPLESS TOOTH

The pulpless tooth, treated or untreated, should not be looked upon as a "dead" tooth, and we would do well to eliminate this term from both our thinking and terminology. If the pulpless tooth were dead, it would be exfoliated by the natural body defenses as a sequestrum. On the contrary, and in light of present knowledge, one of the negative elements concerning the properly treated pulpless tooth is the difficulty of extraction in those cases where this becomes necessary. It would seem that nature is even overprotective in her concern for this step-child of dentistry. Certainly no where else in the operations that we perform in our efforts to keep the dental entity in a state of optimal health and function can we expect to receive more help and cooperation from the magnificent and incredible defensive and reparative mechanisms of the human body. Those among us who are still 100 per cent in the condemnation of the pulpless tooth are missing the pleasure and fascination of one of the most self-satisfying services in dentistry and are denying many patients a service they deserve and have a right to expect. The word has a way of getting around, and there is a noticeable disinclination on the part of the public to have teeth removed. This trend has been observed by the writer who, though a general practitioner, has had many patients referred by other dentists, including oral surgeons, for endodontic treatment because of the patient's intense desire to retain the tooth if possible. It may be observed that the oral surgeons appear to be much better informed as to the present status of endodontics than are the general practitioners.

The practice of root canal therapy is frequently thought of in terms of an extremely difficult procedure, the result of which will be visible in the roentgenograph for all to see in the future. This fact alone has caused many an operator to hesitate to do a root canal treatment, for fear that the roentgenographic result may reflect upon his ability. While it is true that the operation must be precise, immaculate, and meticulous, the same is true of any dental operation, and it is not beyond the ability of any capable dentist. Furthermore, simple techniques have been devised, both for bacteriologic checks and operative procedures, which can be accomplished within a time limit that makes this service economically feasible for both the patient and the dentist.

Prior to endodontic treatment as complete a medical history as possible should be recorded both to ascertain the physical status of the patient and to guard against the possibility of prior existing symptoms being subsequently laid to the treatment. Further, it should never be suggested to the patient that the operation is a risky and doubtful procedure that may possibly end in failure or develop complications.

In a highly suggestible person, a negative suggestion may produce negative results in any type of treatment. The dentist may make note of his own evaluation of the prognosis in a private record for possible future reference.

Though one of the oldest facets in dental practice, endodontics under the modern concept is relatively new; its study and execution are extremely interesting. Although there are at least three excellent books[4-6] which cover the subject beautifully, in addition to the many fine articles which have been published, the reading of books and papers cannot possibly induce the skill and confidence which result from a well-conducted two-week postgraduate course with its clinical experience. A number of these courses are available on all subjects. No less important than the technical instruction in these courses is the inner feeling of inspiration instilled by their dedicated teachers who are with all our other teachers, past and present, the great unsung heroes of dentistry.

SUMMARY AND CONCLUSIONS

1. The pulpless tooth is not a dead tooth.
2. The investigations which led to mass condemnation of the pulpless tooth have been largely discredited.
3. The presence of bacteria in the pulpless tooth is not the sole concern of treatment. With or without bacteria, the canals may harbor highly irritating proteolytic toxins of great potency. In any event the material is *within* the canal.
4. Radiolucent areas about the apices of pulpless teeth represent tissue response to inflammation from irritants within the canal, and are actually the defensive mechanism at work. True cysts are rare.
5. Gentle thorough cleansing and sterilizing, followed by complete obturation of the canal, establishes a situation in which nature can and will repair the damaged tissues.
6. Endodontic treatment, properly executed, can be the means of retaining many strategic teeth in a state of health and function with complete safety and without apology.

REFERENCES

1. Hunter, William: The Role of Sepsis and Antisepsis in Medicine and the Importance of Oral Sepsis as Its Chief Cause, Dental Register **65**:579, 1911.
2. Billings, Frank: Chronic Focal Infections and Their Relation to Arthritis and Nephritis, Arch. Int. Med. **9**:484, 1912.
3. Rosenow, E. C.: Elective Localization of the Streptococcus From a Case of Pulpitis, Dental Neuritis and Myostitis, Int. J. Orth. **11**:713, 1916.
4. Coolidge, Edgar D., and Kesel, Robert G.: Endodontology, ed. 2, Philadelphia, 1956, Lea & Febiger, p. 342.
5. Sommer, Ralph F., Ostrander, F. Darl, and Crowley, Mary C.: Clinical Endodontics, Philadelphia, 1956, W. B. Saunders Co., p. 2.
6. Grossman, Louis I.: Root Canal Therapy, ed. 4, Philadelphia, 1955, Lea & Febiger, pp. 21, 30.
7. Sommer, R. F.: Personal communication.
8. Hedman, W. J.: An Investigation Into Residual Periapical Infection After Pulp Canal Therapy, Oral Surg., Oral Med. & Oral Path. **4**:1173-1179, 1951.
9. Dow, P. R., and Ingle, J. I.: Isotope Determination of Root Canal Failure, Oral Surg., Oral Med. & Oral Path. **8**:1100-1104, 1955.
10. Ingle, J. I.: Root Canal Obturation, J.A.D.A. **53**:47-55, 1956.
11. Grossman, L. I.: Polyantibiotic Treatment of Pulpless Teeth, J.A.D.A. **43**:265. 1951

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THE THIOKOL RUBBER BASE IMPRESSION MATERIALS

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THE DEVELOPMENT OF THE THIOKOL polysulfide liquid polymers for industrial use has been described by Fettes and Jorczak.[1, 2] These materials have been compounded for use as an elastic dental impression material which is becoming increasingly popular. The physical properties of the dental Thiokol rubber base compounds have been investigated and reported by Skinner[3] and by Fairhurst,[4] Hansen,[5] and Clark.[6] Techniques for the clinical use of these materials have been described by Bailey,[7] Burket,[8] Pearson,[9] Pinkerton,[10] Rosentiel,[11] Silver,[12] and Sturdevant,[13] and they have found them to be satisfactory elastic impression materials. Particular advantages are a strong, stable impression with good reproduction of detail, which can be poured in stone or electroformed.

The impression compound is supplied in two collapsible tubes, one containing the base and the other the curing compound. The base consists of Thiokol liquid polymer, most probably of the type LP-2, compounded with filler which, in one brand, consists of zinc oxide and calcium sulfate.[9] The curing compound is lead peroxide, possibly mixed with stearic acid and dibutyl phthalate,[14] or with sulfur and castor oil as in one dental product.[9] The base and accelerator are proportioned by dispensing various lengths on a paper mixing pad or a glass slab as directed by the manufacturer. The materials are mixed with a large, stiff, steel spatula until a uniform color with no streaks is obtained which should be accomplished in 30 to 45 seconds according to instructions.

The initial application of a new material in the dental field is followed by a period of experimentation in adapting the material to meet the requirements of its new uses and in developing techniques to make the best use of the new material. A variety of products become available, each with its own characteristics and properties, and from these, the clinician must select products most suited to his needs. A survey of the physical properties of available products, therefore, gives a rational approach to the selection of products for particular requirements. In this investigation, those physical properties of immediate clinical interest of 12 products (Table I) were investigated. The data obtained formed the basis for the selection of products most suited to a particular clinical procedure. The clinical evaluation was limited to the use of the materials in the production of single and multiple gold inlays. Several techniques were investigated in the first instance, and on the basis

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of simplicity and suitability for routine office use three were finally submitted to clinical trial.

POROSITY

Careful examination of rubber base compound freshly ejected from the supplier's tube reveals the presence of many air bubbles. These can be seen readily if a small quantity of the base material is pressed into a thin film between two sheets of glass and held against a bright light. Most of these bubbles can be eliminated, following mixing, by spreading the mixed material into a thin film on a pad. In this way, the bubbles burst onto the surface and the air escapes.

TABLE I. RUBBER BASE IMPRESSION MATERIALS TESTED

DESIGNATION	TRADE NAME	BATCH NUMBER	DATE OF PURCHASE	MANUFACTURER
A	Static	None	Oct. 5, 1956	Stalite, Inc. New York
B	Form Flex	6171	Oct. 31, 1956	William Getz Corp. Chicago
C	Permlastic Heavy-bodied	641NN231NN242	Sept. 18, 1956	Kerr Manufacturing Co. Detroit
D	Permlastic	662NN554NN654 KK793KK904	Sept. 18, 1956 Oct. 8, 1956	Kerr Manufacturing Co. Detroit
E	Dura Flex	None	Oct. 16, 1956	Reliance Dental Mfg. Co. Chicago
F	Neoplex	16556 27656	Sept. 18, 1956 Oct. 30, 1956	Surgident, Ltd. West Los Angeles, Calif.
G	Plastodent	None	Oct. 19, 1956	Plastodent, Inc. New York
H	Paragel	109	Oct. 11, 1956	Dental Perfection Co. Glendale, Calif.
I	Coe Flex	C5 WW8 E6	Sept. 25, 1956 Oct. 8, 1956 Oct. 15, 1956	Coe Laboratories, Inc. Chicago
J	Permlastic Light-bodied	612100261 00267	Jan. 4, 1957	Kerr Manufacturing Co. Detroit
K	Static "X"	None	Nov. 19, 1956	Stalite, Inc. New York
L	Coe Flex Light-bodied	M2	Jan. 29, 1957	Coe Laboratories, Inc. Chicago

MANIPULATION AND SETTING TIMES

Of particular importance in the selection of a material for a clinical procedure is a knowledge of the time available in which the material can be loaded into a tray or syringe and readied for use. Once the rubber base is in place in the mouth, the

final setting time will determine when it can be removed. The available products present a wide variation of manipulation and setting times and give the clinician a range of values from which to select the product of his choice.

The manipulation and setting times have been determined using a modified Vicat needle as recommended by Skinner.[3] The total weight of the penetrating element was 300 Gms. and the needle was 3 mm. in diameter. Enough material to fill a brass ring 16 mm. in diameter and 8 mm. high was mixed according to the manufacturer's directions. The needle was allowed to penetrate the material for 10 seconds and a reading was taken. This procedure was repeated at 30-second intervals. The manipulation time was taken as that time at which the needle no longer penetrates to the bottom of the ring. The material was considered to be completely set when a constant minimum reading was obtained. The constant minimum penetration varied for each product according to the stiffness of the set material. Product G, for example, had a constant minimum penetration of 0.5 mm., whereas products E, F, and I, had a constant minimum penetration of 3.0 mm.

TABLE II. SETTING TIMES
(Nearest 0.5 minute)

MATERIAL	ROOM CONDITIONS		MOUTH CONDITIONS	
	MANIPULATION TIME (MINUTES)	SETTING TIME (MINUTES)	MANIPULATION TIME (MINUTES)	SETTING TIME (MINUTES)
A	1.5	2.5	1.5	3.0
B	3.0	5.5	3.0	5.0 [1]
C	4.0	5.5	4.0	5.5
D	4.0	6.5	4.0	6.5
E	4.5	7.0	3.5	6.0
F	5.0	7.5	4.0	7.0
G	5.5	8.0	4.0	6.5
H	7.0	10.0	5.5	8.5
I	9.0	12.5	5.5	8.5
J	7.0	11.5	6.5	9.0
K	7.5	11.5	—	—
L	11.0	17.0	7.5	12.0

The first series of tests summarized in Table II were run at room temperature (25° C. ± 1° C.). The second series recorded under mouth conditions were run as follows. The mixes were made on a pad at room temperature and the manipulation and setting times tested in an oven at 37° C. and 100 per cent relative humidity. The Vicat apparatus was placed in the oven and allowed to reach equilibrium conditions prior to testing, and the filled brass ring was placed in the oven within 2 minutes of beginning the mix.

The manipulation times at room conditions vary from 1.5 minutes to 11 minutes. The setting times vary from 2.5 minutes to 17 minutes. Between these values there is a gradual progression from the quick-setting products to the slow-setting products. Under mouth conditions it can be seen that the quicker-setting materials

are not markedly influenced, since materials C and D have the same values under both conditions, but the slower-setting materials set more rapidly under mouth conditions: material I, for example, has the manipulation time reduced by 3.5 minutes and setting time by 4 minutes.

Clinical experience with the light-bodied materials showed that these products set much more quickly once the tray had been seated than their behavior in bench tests would indicate. Frequently the material left in the syringe was still capable of ejection at the time the impression was ready for removal. Laboratory tests showed that the slow-setting light-bodied materials are accelerated in setting rate by contact with the heavier-bodied quick-setting products.

The quicker-setting materials lend themselves to techniques requiring the mixing of only small quantities of material and the use of procedures not requiring much time as in a copper band impression technique. In contrast, techniques requiring larger quantities for partial or complete denture impressions call for a longer-setting material. The slow-setting materials J and L have been developed for use in a syringe and allow time for mixing of a heavy- and light-bodied material and the loading of both a syringe and an impression tray.

EFFECT OF VARIATIONS IN PROPORTIONING

The rubber base materials are mixed in proportions of equal lengths, half lengths, or similar amounts of base and accelerator materials furnished in tubes. With such a procedure, errors of proportioning are possible in clinical use. To ascertain the effect of such errors on manipulation and setting times, products D and I were tested using two-thirds the amount of base recommended and also two-thirds the amount of accelerator recommended. The results of these tests (Table III) show that I is noticeably affected by changing amounts of accelerator while product D is relatively unaffected.

TABLE III. VARIATIONS IN ROOM TEMPERATURE SETTING TIME IN MINUTES WITH CHANGING BASE TO ACCELERATOR RATIOS

MATERIAL	1:2/3		1:1		2/3:1	
	MANIPULATION TIME	SETTING TIME	MANIPULATION TIME	SETTING TIME	MANIPULATION TIME	SETTING TIME
D	4.5	7.0	4.0	6.5	4.0	6.0
I	11.5	16.0	9.0	12.5	8.0	11.0

CONSISTENCY

A comparison of the consistency of the rubber base compounds was obtained by measuring the average diameter of a disk of the material flattened between two glass plates by a standard weight. A measured quantity of the material (0.1 ml.), mixed according to the manufacturer's directions, was placed between two glass plates. Two minutes after the start of the mix a 500 Gm. weight was placed on the

top glass plate. The weight was removed after a total of 10 minutes and the average diameter of the disks recorded. These values are reported in Table IV and show a range from 12 mm. to 34 mm. Five of the twelve materials fall in the 25 to 26 mm. group. Product C is recommended by the manufacturer for use in an impression tray along with product J in a syringe, and this combination works well. Product L is recommended for use in a syringe with product I in the tray.

These syringe materials tend to drip out of cavities in the upper arch and probably a consistency value of 28 to 29 would be ideal for use in a syringe.

TABLE IV. CONSISTENCY TESTS

MATERIAL	DISK DIAMETER (MM.)	ROOM TEMPERATURE SETTING TIME (MINUTES)
A	12	2.5
B	19	5.5
C	23	5.5
D	25	6.5
E	20	7.0
F	22	7.5
G	26	8.0
H	25	10.0
I	26	12.5
J	34	11.5
K	25	11.5
L	32	17.0

SET AND STRAIN CHARACTERISTICS

The set and strain properties of nine rubber base materials have been determined at room temperature using the test outlined in A.D.A. Specification No. 11 for hydrocolloid impression materials.[15] Skinner[3] tested the strain and set values of the rubber base materials after hardening for 30 minutes at room temperature and also 3 minutes after setting. When tested after 30 minutes hardening, the strain and set values of all the materials tested were within the range of the A.D.A. specification for hydrocolloids. When tested 3 minutes after set, the values of percentage set of some materials were higher than the specification limit.

In this investigation, the products were tested 10 minutes after the commencement of mixing. At the time this test was designed and carried out, the light-bodied compounds were not available, and clinical techniques made use of only one mix; 7 to 8 minutes seemed a suitable time for mixing, loading a band or tray, placing material in the cavity, seating the band or tray, and for setting to occur. Allowing for a possible slower set at room temperature, the material would be subjected to strain during removal from the mouth 10 minutes from the beginning of the mix.

The values of strain and permanent deformation obtained are listed in Table V. All the products fall within the limits set for per cent strain in A.D.A. Specification No. 11 for hydrocolloids. Only three materials fulfill the requirements for per cent permanent deformation when tested at 10 minutes. Those products, such as H and I, which have a setting time close to or greater than 10 minutes, exhibit poor strain

and set properties in this test, and it is not concluded that they are unsatisfactory materials. These slower-setting products can be used in techniques requiring longer manipulation time and could be removed from the mouth at a later stage in their set than in this test. Such times are indicated in Table II which gives the setting times of these products for both room and mouth conditions of temperature and humidity. It is concluded that the rubber base materials will exhibit varying degrees of permanent distortion on removal from the mouth. This distortion can be minimized by holding the impression in place as long as possible, allowing the reaction to proceed as completely as is reasonable with patient comfort.

TABLE V. SET AND STRAIN PROPERTIES TESTED AT ROOM TEMPERATURE TEN MINUTES AFTER START OF MIX

MATERIAL	STRAIN %	SET %
A	6.13	1.52
B	8.40	4.20
C	4.57	2.18
D	7.49	2.18
E	14.50	6.06
F	14.96	4.60
G	7.50	3.93
H	17.30	11.46
I	17.40	15.76
A.D.A. Spec. No. 11 values	4–20	less than 3.0

CLINICAL PROCEDURES

Early experiments with the rubber base impression compounds showed that attempts to make impressions with a copper band or a tray failed to register the deeper areas of a cavity preparation in which air had become trapped. It became apparent that some of the material must be introduced into the cavity prior to placing the band or tray. Initially, this was done with a small plastic instrument or a brush, and this is satisfactory for simple impressions using a copper band and for impressions of Class V cavities. More recently, the production of light-bodied materials which are sufficiently fluid for use in a syringe provides a satisfactory solution to the problem of filling the cavity prior to placing a tray full of material.

One product goes through a nonsticky stage in which it can be handled with moistened fingers. In this stage, it can be formed into a cone or other suitable shape and driven into the cavity with finger pressure. A trayful of the same mix is then carried to place.

Three clinical procedures have been investigated: the syringe and tray technique, a method in which the material is driven into the cavity with finger pressure prior to placing a tray, and the copper band technique.

SYRINGE AND TRAY TECHNIQUE

Several suitable syringes are now commercially available and all make use of a plastic nozzle which can be replaced from time to time.

Two light-bodied products are available for use in a syringe, and their manipulation and setting times are seen in Table II. Product L gives a longer manipulation time than product J and is best used where large areas are involved as in bridgework; the shorter-setting product J is good for use in inlay cases where smaller areas are involved. A heavier-bodied material is used in the tray. Product J is used with either C or D products giving a choice of a heavy or medium-bodied tray material. Product L is used with product I in the tray.

The use of a tray made or adapted for each case has the advantage of reducing the amount of material required. Smaller quantities are easier to mix and are more economical. Special trays can be fabricated from self-curing acrylic or baseplate material on a study cast. Fig. 1 shows a tray adapted at the chairside from perforated metal to which a handle is fixed by means of a self-tapping thread attached to the handle. This makes a disposable tray; the handle is used repeatedly. The perforated tray metal can be bought from the supply houses, but the detachable handle has been developed by the authors and is not commercially available at present. Such a handle can be made readily from a short length of ½ inch hard brass strip. A gauge 4 quarter-inch plate screw is screwed through a hole at one end of the brass strip and soldered in place, and the head is ground off (Fig. 1). Trays should be rigid and well adapted to give 3 to 4 mm. clearance (Fig. 2).

Occlusal stops can be made of wax, modeling compound, or self-curing acrylic resin. An adhesive is desirable where acrylic resin trays are used, but is not necessary with the perforated metal tray described above.

To achieve an adequate impression of the cervical area of cavities, control of the gingival tissue is desirable. This can be achieved by the placing of string packs in the gingival sulci, and leaving them in place for 5 to 7 minutes before making the impression. The string is carefully packed down into the gingival sulcus. On removal, an open ditch is present at the cervical margin into which the rubber base flows and registers an accurate impression of the area beyond the cervical cavosurface angle.

Injection of the light-bodied rubber base is started as soon as the packs are removed. The cervical areas of the most distal preparation are filled first, the syringe nozzle touching the interior cavity walls as the other cavities are filled from cervical to occlusal. The syringe nozzle is moved around into every extension of the cavities in order to displace all air.

Following the injection of the light-bodied material, the tray of heavy-bodied material is carried to place and left in position until set. The exact time will vary with different products and with humidity and temperature conditions. Clinically, the degree of set can be checked by indenting an exposed area of the rubber with a blunt explorer and noting the recovery.

Observations in over 500 impressions made on laboratory bench models and in the clinic indicate that a snap removal is not essential with these materials, and that they can be removed slowly if preferred, without loss of clinical accuracy.

Upon removal, the impression is set aside for one-half to one hour, during which time the elastic properties of the material continue to improve, and the risk of distortion during pouring is reduced. This improvement of the elastic properties of the rubber base materials during the first hour after mixing was demonstrated in

work done at the National Bureau of Standards and reported at the Atlantic City meeting of the Dental Materials Group of the International Association for Dental Research in March, 1957.[5] The impression can be poured in stone and the inlays constructed by any of several well-known techniques. Two clinically accurate stone dies can be formed from one impression. If metal dies are preferred, the impression can be electro-plated in copper or silver, the latter being the easier procedure.

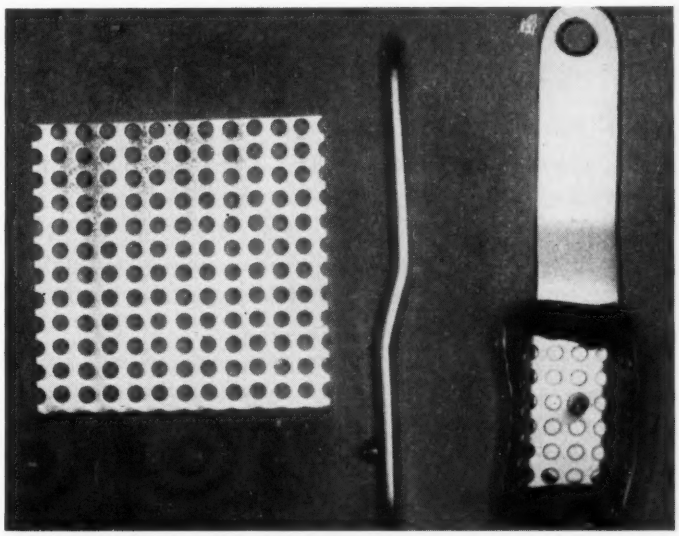

Fig. 1.—*A*, Perforated sheet metal; *B*, handle with self-tapping screw; *C*, assembled tray with occlusal stops.

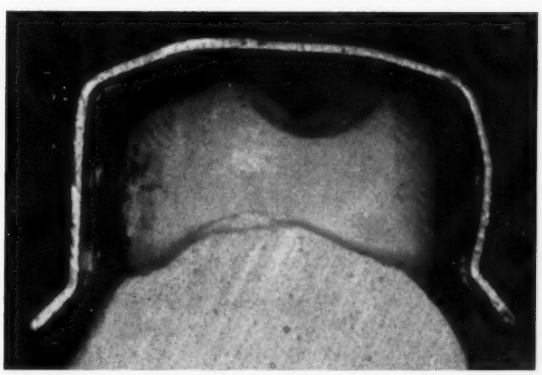

Fig. 2.—Section through a stone cast and tray to show the type of adaptation desirable to reduce the quantity of material and to attain good compression.

TRAY TECHNIQUE WITHOUT THE SYRINGE

One product (F) passes through a nonsticky stage in which it can be molded in the moistened fingers in a similar manner as softened modeling compound. This

stage develops about 3 minutes from the beginning of mix and continues for 1 minute before elastic properties begin to develop. In warm, humid weather these times are shortened a little.

In using this material, the tray is loaded immediately following mixing. The gingival packs are removed and the cavities are dried with cotton pellets. By this time, the material is entering the nonsticky phase. A small cone just large enough to fill a cavity is driven firmly into the interproximal box of the cavity, and this procedure is repeated for each cavity. Excess material is packed into the occlusal area of the cavities, and the tray is then carried to place. When set, the impression is removed and the procedure described above is followed for forming the dies or cast.

COPPER BAND TECHNIQUES

Although the elastic impression materials lend themselves to use in tray impression techniques, and undoubtedly they will be used mainly in this way, occasions may arise when the individual copper band impression will be preferred. Difficult soft tissue relations, or the need for a single metal die, may be indications for this procedure. Experiments have been carried out with perforated bands and with oversized bands, but the best results have been achieved with plain, unannealed bands, and the use of an adhesive. In making an impression of an intracoronal restoration, a slightly undersized copper band is trimmed to rest on the height of contour of the tooth, and to go to place with no distortion or spring. The occlusal end of the band is filled with a compound plug for reinforcement, and the inside of the band is given a thin coat of adhesive and put aside for the adhesive to set. A quick-setting rubber base impression material is mixed and the band is filled. A small quantity of rubber base impression material is placed in the deep parts of the cavity and in the occlusal areas where air may be trapped, the band carried to place, and the material allowed to set. Following removal, the impression is allowed one-half to one hour before pouring or electroforming the die.

Where the copper band technique is used for full crown preparations, a stop for seating the band is achieved by adapting the compound occlusal plug to extend onto the occlusal surfaces of each adjacent tooth. This extension can be reinforced by means of a lug from the copper band.

Such impressions have proved accurate provided the band does not enclose any quantity of material in the external undercuts of the tooth, and provided it goes to place without distortion. Care is necessary in removal lest the band be squeezed and distorted.

SUMMARY

Some physical properties of the Thiokol rubber base impression materials have been investigated. The manipulation and setting times of products have been determined at room temperature and 37° C. The effect of variations in proportioning of base and catalyst has been determined and a comparative evaluation of the consistency of products conducted. The per cent set and per cent strain characteristics have been determined 10 minutes after the start of mixing. This 10-minute time was chosen because it represents a practical time interval for clinical use. A clinical evaluation has studied the behavior of some of these products in three techniques.

CONCLUSIONS

1. All the products examined contained air bubbles when freshly ejected from the tube. Most of these bubbles can be eliminated by suitable manipulation following mixing.

2. The twelve products tested showed variations in manipulation time from 1.5 minutes to 11.0 minutes, and in setting time from 2.5 minutes to 17.0 minutes at room temperature.

3. Increase in humidity and temperature speeded up the setting of the rubber base products. The setting of the slow-setting products was significantly speeded. The faster-setting products were less affected.

4. The setting of the slow-setting products was speeded by contact with the fast-setting products.

5. Some products are more affected by variations in proportioning than others.

6. Products tested gave a range of consistency values from 12 mm. to 34 mm. Those materials designed for use in a syringe have values around 32 to 34 mm. These products have a tendency to drip from cavities in the upper arch, and probably consistency values in the range of 28 to 29 mm. would be ideal for syringe use.

7. Provided that the rubber base materials are allowed to set sufficiently before removal from the mouth, their properties of per cent strain and per cent set are good.

8. Clinical tests showed that the three techniques employed gave inlays of good quality. A very excellent cervical adaptation was noted as being an outstanding general characteristic of inlays prepared by techniques using the rubber base products.

REFERENCES

1. Fettes, E. M., and Jorczak, J. S.: Polysulphide Polymers, Indust. & Engin. Chem. **42**:2217, 1950.
2. Jorczak, J. S., and Fettes, E. M.: Polysulphide Liquid Polymers, Indust. & Engin. Chem. **43**:324-328, 1951.
3. Skinner, E. W., and Cooper, E. N.: Desirable Properties and Use of Rubber Impression Materials, J.A.D.A. **51**:523-536, 1955.
4. Fairhurst, C. W., Furman, T. C., Schallhorn, R. V., Kirkpatrick, E. L., and Ryge, G.: Elastic Properties of Rubber Base Impression Materials, J. Pros. Den. **6**:534-542, 1956.
5. Hansen, W. C., and Miller, W. A. C.: Specification for Rubber Base Impression Materials, Dental Materials Group, Internat. Assoc. Dental Research, Atlantic City, March, 1957.
6. Clark, R. J., and Phillips, R. W.: Flow Studies of Certain Dental Impression Materials, J. Pros. Den. **7**:259-266, 1957.
7. Bailey, L. R.: Acrylic Resin Tray for Rubber Base Impression Materials, J. Pros. Den. **5**:658-662, 1955.
8. Burket, J. F.: Application of Synthetic Rubber Impression Material to Pedodontic Procedures, J. New Jersey D. Soc. **26**:7-9, 1955.
9. Pearson, S. L.: New Elastic Impression Material: A Preliminary Report, Brit. D. J. **99**:72-76, 1955.
10. Pinkerton, R. G.: Techniques of Rubber Base Impressions, D. Digest **62**:394-397, 1956.
11. Rosentiel, E.: Rubber Base Elastic Impression Materials (A Preliminary Note), Brit. D. J. **98**:392-394, 1955.
12. Silver, M.: Impressions and Silver-plated Dies From a Rubber Impression Material, J. Pros. Den. **6**:543-549, 1956.
13. Sturdevant, C. M.: Impressions for Indirect Inlays, J.A.D.A. **54**:357-366, 1957.
14. Thiokol Liquid Polymers, Thiokol Chemical Corporation, Nov., 1955, Trenton, New Jersey.
15. A.D.A. Spec. No. 11 for Hydrocolloidal Impression Material, Am. Dent. Assoc. Specifications for Dental Materials, ed. 2, Chicago, 1956, American Dental Association.

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A STUDY OF PARTIAL DENTURE DESIGN AND MASTICATORY PRESSURES IN A MANDIBULAR BILATERAL DISTAL EXTENSION CASE

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THE PHYSIOLOGY OF MASTICATION encompasses the entire masticatory system. A derangement of any one of its component parts could result in masticatory insufficiency. Occlusion that is defective or inadequate is compensated for by either changes in dietary or masticatory habits. Dietary changes may be such as to produce nutritional deficiencies and also deprive the individual the pleasures of "good eating." Masticatory habits may be changed because of pain, fear of pain, ineffectual mastication, or lack of occlusion.[1] Food that is insufficiently masticated and swallowed will burden the gastrointestinal system which could lead to, or aggravate existing, systemic disorders.

The loss of all posterior mandibular molars presents a serious prosthodontic problem. Adequate replacement requires the restoration of masticatory efficiency and the preservation of the remaining teeth and associated structures. The patient is a "dental cripple," and the partial denture prosthesis is his "dental crutch." The effectiveness and usefulness of the partial denture will depend upon its design. It is the design of the partial denture that will evoke favorable or unfavorable biologic responses of the supporting structures to masticatory and nonmasticatory pressures.

In a previous partial denture study,[2] the effect of partial denture design upon force distribution and masticatory performance was studied on a mandibular unilateral distal extension denture. Mastication was accomplished primarily on the tooth-borne side because of masticatory habit and comfort.

The objective in this undertaking is to study, by electronic means, the effect of partial denture design on functional force distribution in a mandibular bilateral distal extension denture as it is related to the supporting tissues. In addition, a study will be made to determine what effect the variations of partial denture designs has on masticatory performance. The influence of the size of the occlusal table on force distribution and masticatory performance will also be studied.

TEST PARTIAL DENTURE

A patient was selected for whom a mandibular bilateral distal extension partial denture was indicated. The maxillary arch had been previously restored by means

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The opinions or assertions contained herein are those of the author and are not to be construed as official or as reflecting the views of the Navy Department or the Naval Service at large.

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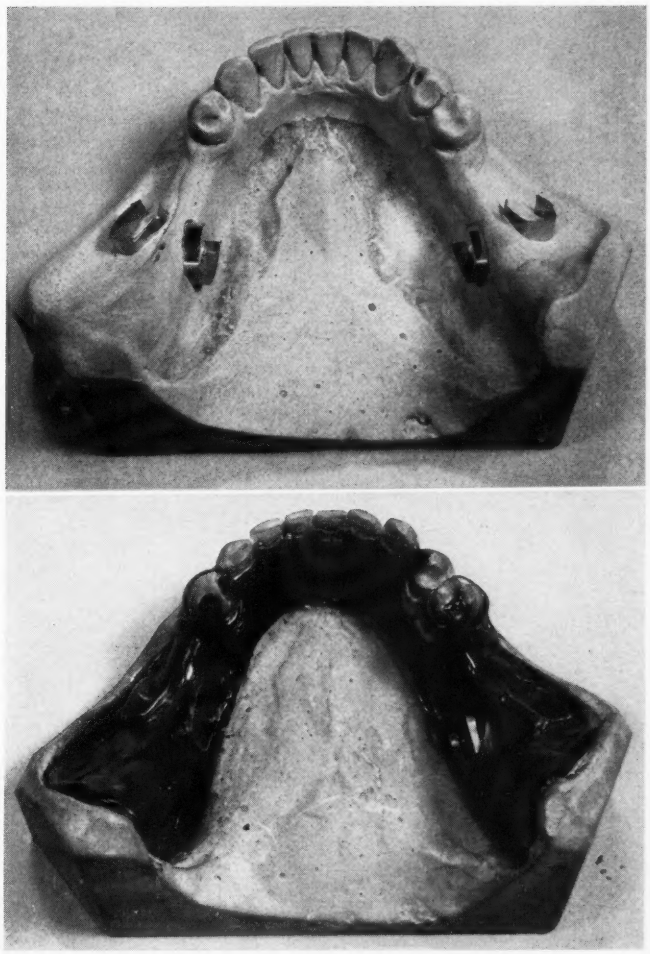


A.

B.

Fig. 1.—*A*, The refractory investment cast with stainless steel inserts in place in order to create in the denture base isolated springboards to be used as measuring sites. *B*, The wax-up completed.

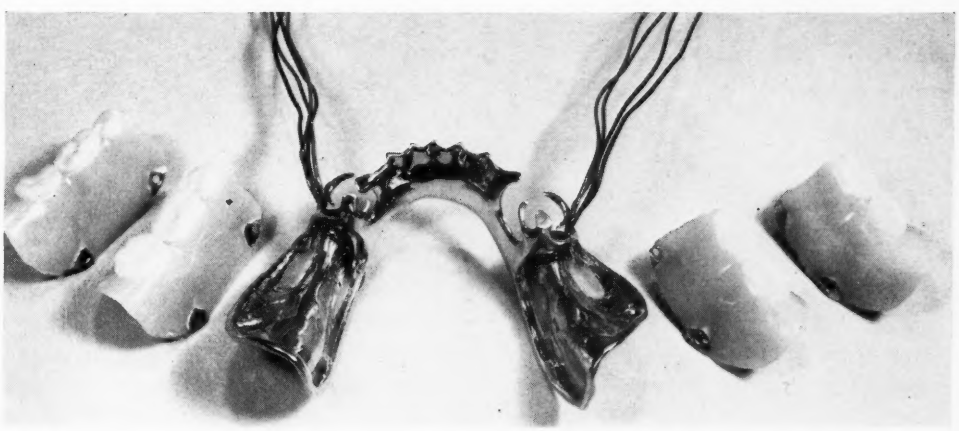


Fig. 2.—The test partial denture used in the studies with the interchangeable occlusal sections.

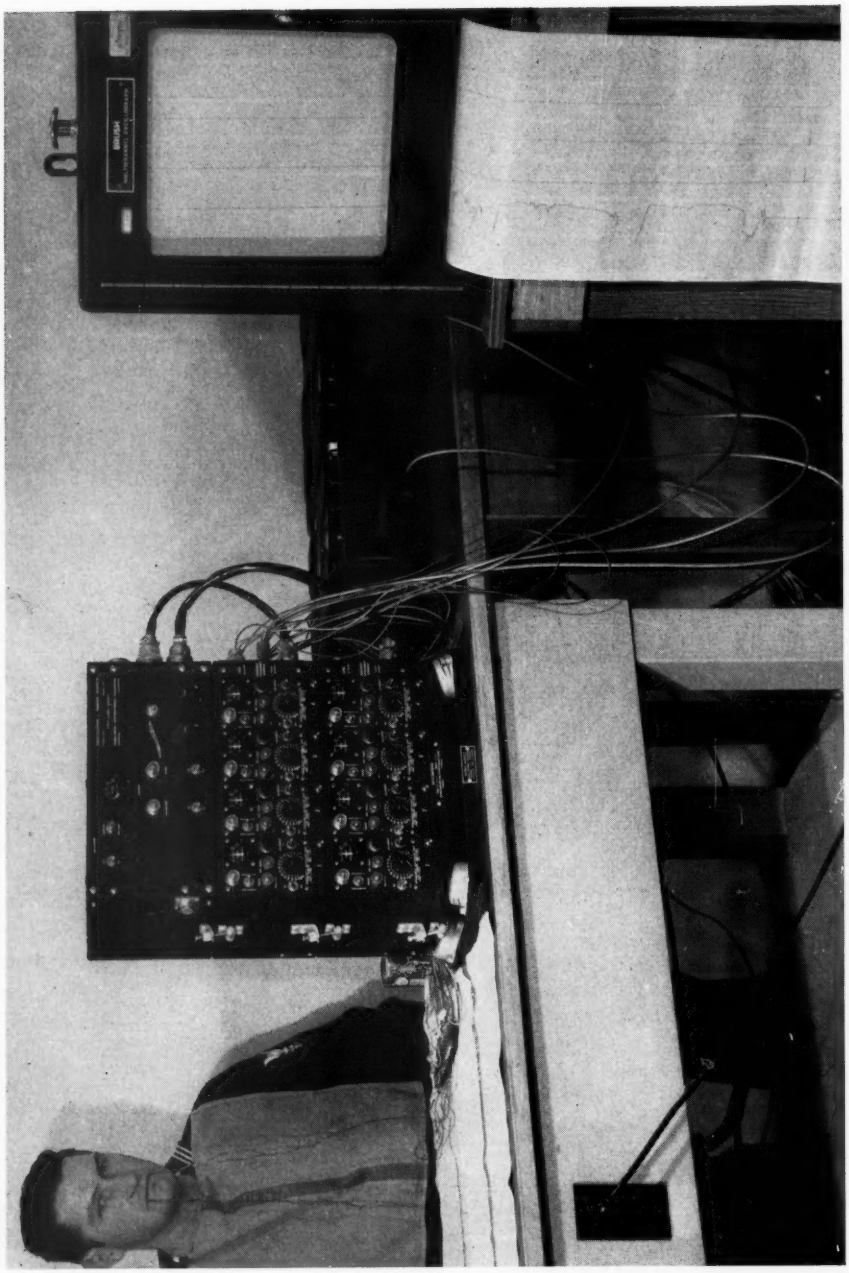


Fig. 3.—The patient and the electronic testing equipment used in the studies.

of fixed crown and bridge prosthesis. The ridges were well-formed, and an adequate interarch space was present to permit the fabrication and placement of interchangeable occlusal tables.

Centric occlusion and centric relation were found to be in harmony. The abutment teeth were prepared for occlusal rests. Maxillary and mandibular impressions were made, and casts were poured in artificial stone. The mandibular impression was made with a technique employing slight pressure in order to obtain slight displacement of the soft tissues.

Two partial dentures of similar design were fabricated. One was used as a service partial denture. The design of the service partial denture included the use of bar type clasps (T) on the right second bicuspid and the left first bicuspid, a rigid lingual bar connecting wide denture bases, and a continuous bar retainer with mesio-occlusal rests as indirect retainers on both first bicuspids. Trubyte New Hue 33 degree posterior teeth, mold 30S, were used as posterior replacements. The service partial denture was worn for two months, prior to any testing procedures, to accustom the patient in the wearing of a prosthetic appliance and to attain maximum masticatory efficiency as suggested by Abel and Manly.[3] The other, a gold test partial denture, was fabricated to determine the effect of various partial denture designs on the distribution of force upon the supporting tissues.

The design of the gold test partial denture included the use of bar type clasps (T) on the right second bicuspid and the left first bicuspid, a lingual plate connecting wide denture bases, and mesio-occlusal rests as indirect retainers on both first bicuspids. Four isolated springboards were incorporated in the gold denture base to serve as measuring sites for the reception of Baldwin SR-4 type strain gauges. The springboards were designed in the gold denture base in a manner similar to that as reported in a previous study.[2] The springboards were located 10 mm. distal to the bicuspid abutments in widely separated areas buccally and lingually on both the right and left sides (Fig. 1).

Interchangeable occlusal sections were fabricated similar to those reported in a previous study.[2] The gold reinforced interchangeable sections were designed for a large occlusal table and a relatively small occlusal table, using Trubyte New Hue 33 degree posterior teeth, molds 34S and 28S, respectively (Fig. 2). Interchange of the sections was accurate and easily performed. The sections after positioning were made secure by means of screws.

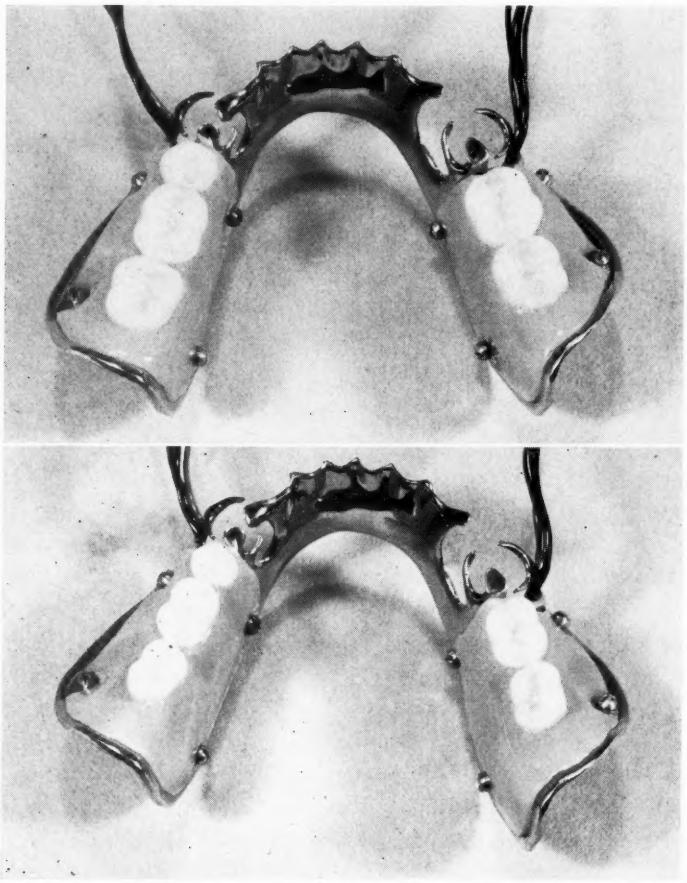
Occlusal corrections of the interchangeable occlusal tables were made on the articulator to remove any processing errors. The result was a test partial denture, with a gold denture base, upon which interchangeable occlusal tables could be placed easily and accurately.

Four Baldwin SR-4 type strain gauges were cemented into place upon the four isolated springboards. The gauges were rendered moisture-proof by means of suitable adhesives. The electronic circuitry included a standard Wheatstone bridge, with amplifiers and a multichannel Brush recorder to amplify and record the pressures exerted upon the supporting tissues (Fig. 3). Compensating gauges were used to provide the necessary balance in the electronic circuitry. The calibration of each springboard was accomplished in a manner similar to that described

by Frechette.[4] Only positive deflections were measured and recorded. Negative deflections were noted as to their occurrence and location.

The series of partial denture designs studied were as follows: (1) the test denture as it was designed originally (Fig. 4); (2) the lingual plate was altered to become a continuous bar retainer (Fig. 5); (3) the continuous bar retainer was removed (Fig. 6); (4) the indirect retainers were removed (Fig. 7); and (5) the rigid lingual bar was reduced so it would be a flexible bar (Fig 8).

A.



B.

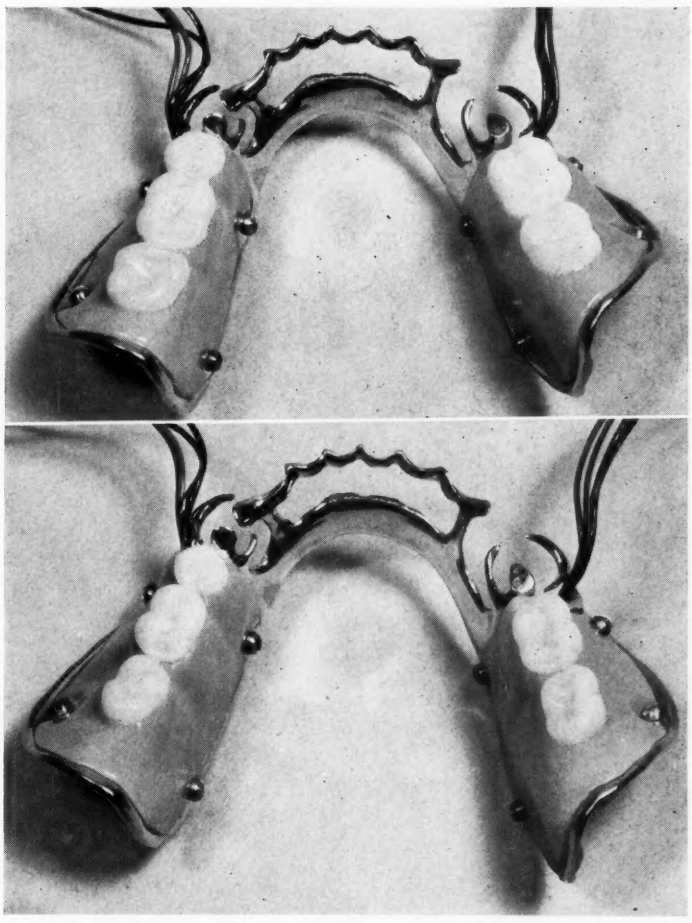
Fig. 4.—*A*, The test denture as it was designed originally. The large occlusal table is in position. *B*, The same partial denture design as in *A*, except the small occlusal table is in position.

TESTING PROCEDURES

The test food used in the studies was peanuts (cocktail, salted). With the electronic circuitry in balance, and with the large occlusal tables in position and secured, the patient was given a 3 Gm. portion of peanuts and was instructed to place and chew the peanuts on the right side of his mouth, his preferred side. The

recorder recorded four simultaneous tracings in the form of deflections produced by masticatory pressures at the springboards. The procedure was carried out for the left side of the mouth and also for random chewing. This procedure was repeated until three satisfactory records were obtained for each situation. These records were then measured for the height of deflection for each chewing stroke, and the pressure per stroke was recorded. The average pressures were determined for each springboard.

A.



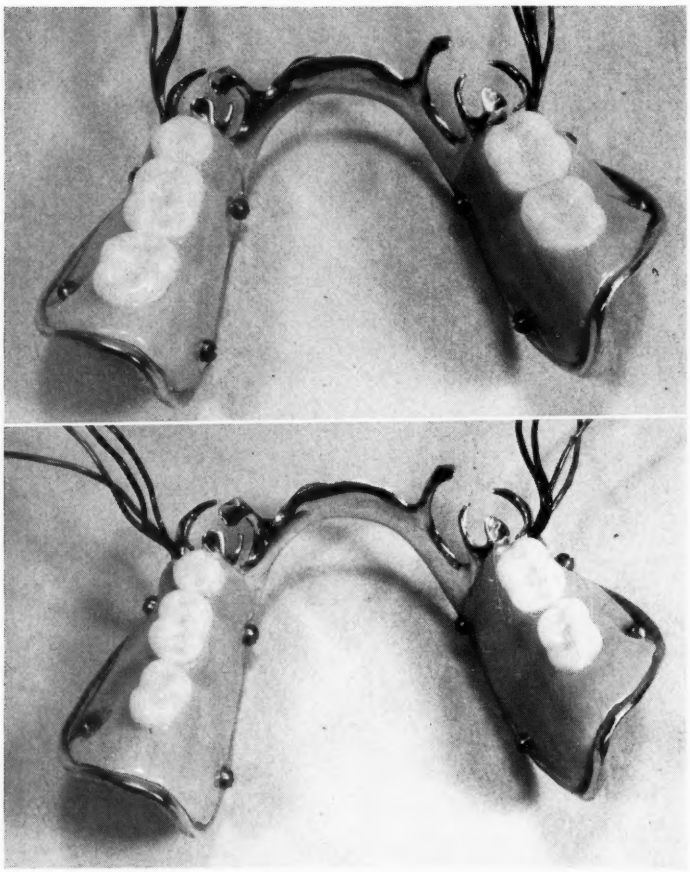
B.

Fig. 5.—*A*, The lingual plate was altered to become a continuous bar retainer. The large occlusal table is in position. *B*, The same partial denture design as in *A*, except the small occlusal table is in position.

The large interchangeable occlusal table was removed and replaced with the small occlusal table, and the procedure was repeated.

The method used to determine masticatory performance was that suggested by Yurkstas and Manly.[5] Three gram portions of peanuts were presented to the

A.



B.

Fig. 6.—*A*, The continuous bar retainer was removed. The large occlusal table is in position. *B*, The same partial denture design as in *A*, except the small occlusal table is in position.

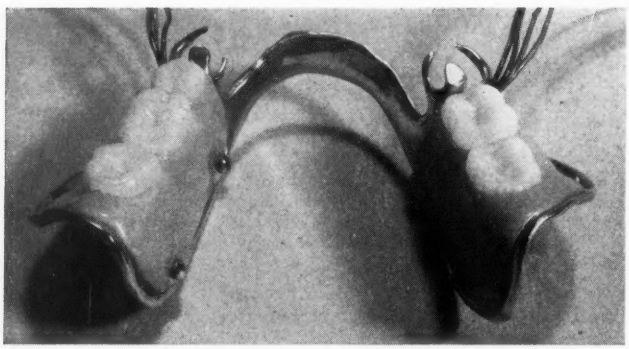
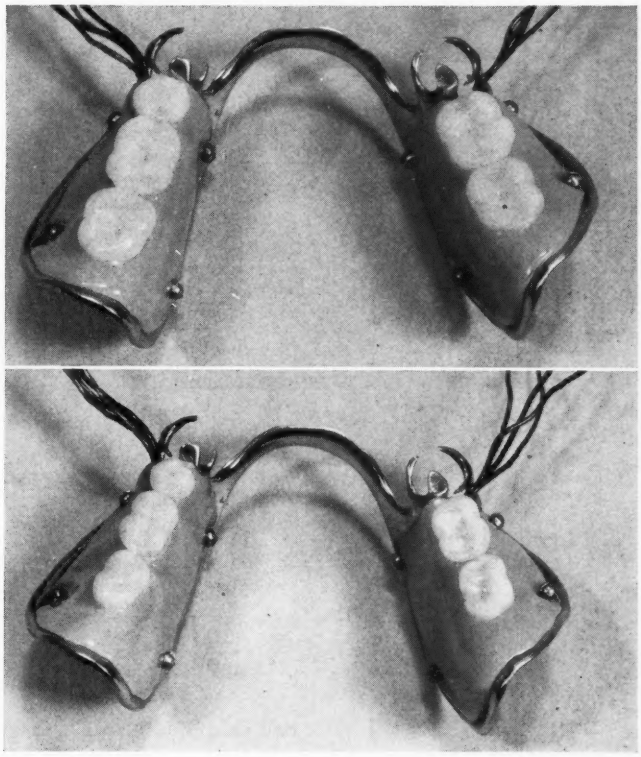


Fig. 7.—The indirect retainers were removed. The large occlusal table is in position.

patient, who was instructed to chew the peanuts for 20 strokes on a given side of the mouth and to expectorate the chewed particles into a beaker. This procedure was repeated with 5 portions of peanuts. The combined chewed particles were washed on a 10-mesh screen (U.S. Standard Sieve Series). Volumetric measurements were made, and the masticatory performance was computed by dividing the volume of the particles passing the 10-mesh screen by the total volume of food recovered from the mouth. The procedure was carried out for each side of the mouth and also for random chewing. It was performed with the large and small occlusal tables.

A.



B.

Fig. 8.—*A*, The rigid lingual bar was reduced so it would be a flexible bar. The large occlusal table is in position. *B*, The same partial denture design as in *A*, except the small occlusal table is in position.

The partial denture was removed, modified, and replaced. The testing procedure was repeated for both force distribution and masticatory performance with both the large and small occlusal tables. This procedure was followed for each modification, and data were compiled.

GENERAL OBSERVATIONS

The deflections produced by the masticatory pressures were recorded on a Brush recorder. The reaction of a particular springboard to a given situation was

either to produce positive deflections, to remain passive, or to produce negative deflections, or a combination of positive-negative deflections. Only the positive deflections were measured and recorded, including the positive aspect of the positive-negative deflections.

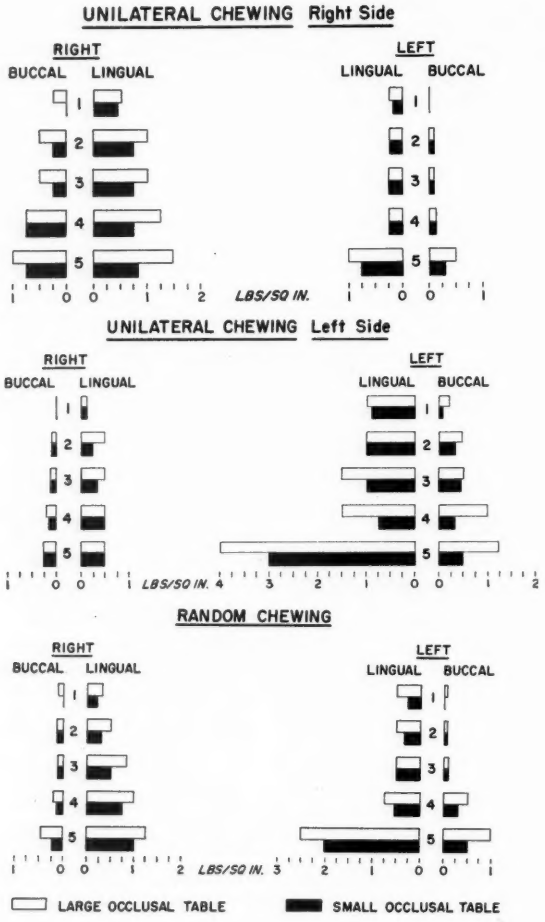


Fig. 9.—The average pressures that were recorded at the measuring sites in the study to determine the effect of partial denture design on force distribution.

By counting the number of deflections, it was possible to determine the number of strokes it took to masticate the prescribed amount of peanuts. It was found that with the large occlusal table, including all modifications, it took an average of 22.31 strokes on the right side; 23.26 strokes on the left side; and 23.50 strokes with the patient chewing at random. With the small occlusal table, including all modifications, it took 25.42 strokes on the right side; 28.00 strokes on the left side; and 26.95 strokes with the patient chewing at random. The time to accomplish the mastication ranged from 12 to 16 seconds, irrespective of the side used. It was also observed that the patient generally required two swallows for each bolus of food.

The patient preferred the small occlusal table. His preference was based upon the subjective impression that he could masticate his food with greater ease and comfort due to better control of the bolus of food and with less "clogging of the teeth." Objectively, it was determined that the masticatory performance with the small occlusal table, including all modifications, was reduced approximately 9 per cent irrespective of the side used for chewing. Further, it required 14 per cent fewer masticatory strokes with the large occlusal table to accomplish the chewing. However, this reduction of masticatory performance with the small occlusal table was compensated for by a *marked* reduction of pressures upon the supporting tissues, particularly in the final stages of denture modification.

All modifications to the partial denture for these comparative studies could be valid only when the modification under consideration was compared to the previous modification.

SUMMARY OF FINDINGS

The average pressures derived from each of the strain gauges for the various partial denture designs were recorded under conditions in which (1) a large occlusal table, and (2) a small occlusal table were used and with the patient chewing on the (a) right side, (b) left side, and (c) at random (Fig. 9.).

The masticatory pressures were found to be relatively stable for the various partial denture designs tested, except in the final modification in which increased pressures were noted. It was found that on the chewing side the masticatory pressures were from 25 to 50 per cent greater when the large occlusal table was used.

The results on masticatory performance are presented in Table I. It was found that with the small occlusal table, including all modifications, the masticatory performance was reduced approximately 9 per cent, irrespective of the side used.

TABLE I. MASTICATORY PERFORMANCE

	RIGHT SIDE		RANDOM		LEFT SIDE	
0.	29.62		29.62		12.0	
00.	61.71		61.71		60.87	
	Large	*Small*	*Large*	*Small*	*Large*	*Small*
1.	50.00	49.02	47.00	44.00	43.75	43.13
2.	54.85	53.85	48.15	50.00	41.17	42.31
3.	61.22	53.57	58.33	50.00	53.06	46.43
4.	59.25	59.15	61.22	55.31	56.00	46.49
5.	55.31	50.00	59.09	50.00	56.00	49.02

O, The masticatory performance that was computed with the remaining natural dentition. OO, The masticatory performance that was computed with the service partial denture in place. 1, The test denture as it was designed originally. 2, The lingual plate was altered to become a continuous bar retainer. 3, The continuous bar retainer was removed. 4, The indirect retainers were removed. 5, The rigid lingual bar was reduced so it would be a flexible bar.

CONCLUSIONS

The findings in this study are similar to those previously reported,[2] namely that: (1) The reduction of the size of the occlusal table reduces the forces acting

on the partial denture and lessens the stresses on the abutment teeth and supporting tissues. (2) The effect of partial denture design on masticatory performance did not reveal any significant relationship. (3) The findings of the effect of partial denture design on the distribution of force upon the supporting tissues were inconclusive. Generally, it can be stated that a rigid design is more desirable than a flexible one. Specifically, a rigid lingual bar is more desirable than a flexible bar in withstanding horizontal stresses.

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REFERENCES

1. O'Rourke, J. T.: Significance of Tests for Biting Strength, J.A.D.A. **38**:627-633, 1949.
2. Kaires, A. K.: Partial Denture Design and Its Relation to Force Distribution and Masticatory Performance, J. Pros. Den. **6**:672-683, 1956.
3. Abel, L. F., and Manly, R. S.: Masticatory Function of Partial Denture Patients Among Navy Personnel, J. Pros. Den. **3**:382-392, 1953.
4. Frechette, A. R.: Masticatory Forces Associated With the Use of Various Types of Artificial Teeth, J. Pros. Den. **5**:252-267, 1955.
5. Yurkstas, A., and Manly, R. S.: Value of Different Test Foods in Estimating Masticatory Ability, J. Appl. Physiol. **3**:45-53, 1950.

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ELECTROMYOGRAPHY IN DENTAL RESEARCH: PART I. GEOMETRIC PLACEMENT OF REFERENCE ELECTRODES

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THE CONSIDERABLE INTEREST currently generated in the application of electromyographic recordings to the examination of facial muscle activity in the field of dentistry has prompted us to examine with some care the biophysical factors underlying such recording. In the course of this examination, it became apparent that there were several possible pitfalls into which researchers might fall in arriving at conclusions based on EMG tracings. It is hoped that the results of our examination may help to circumvent these hazards.

A survey of the recent literature indicated that most workers[1-6] have relied on measurements utilizing single electrodes as references, whereas our preliminary observations indicated that the spread of electrical fields in conducting tissues of the head[7] frequently led to augmentations or cancellations at two electrodes. Thus, it became apparent that a study of the reliability of data taken from various electrode configurations was in order.

Logic would dictate that there exist two possible approaches to such a study: (1) a thorough mapping of isopotential contours in the tissues of the head, with specific and localized activity of individual muscles or muscle groups, and (2) a systematic comparison of recordings made with different kinds and locations of reference electrodes, during various mandibular excursions. Although the first of these represents the most direct approach, the complexity of distribution of tissues of various conductance in the head foretold considerable difficulties in making and interpreting such studies. Studies of the second type, on the other hand, are of direct utility to the dental researcher, and the techniques called for are well within the realm of possibility. For these reasons, the problem of the determination of "best" electrode placement was approached empirically. This article will describe the results of the studies made toward the solution of this problem.

METHODS AND PROCEDURES

All recordings utilized in this study were made with an ink-writing Grass Model III-D electroencephalograph which has a frequency response curve flat to

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more than 70 c.p.s. The amplifiers were operated at sensitivity settings recommended for EMG tracings, such that an input signal of 50 microvolts produced a pen excursion of 0.6 mm. Recording was made at a paper speed of 3 cm. per second.

Surface electrodes were used exclusively in this study. The electrodes were attached by rubbing the skin surface with acetone and then electrode jelly, applying more jelly to the electrode, and taping the electrode to the skin. In every case, the interelectrode resistance was measured with a standard ohmmeter, and tracings were not made unless the resistance was well below 10,000 ohms.

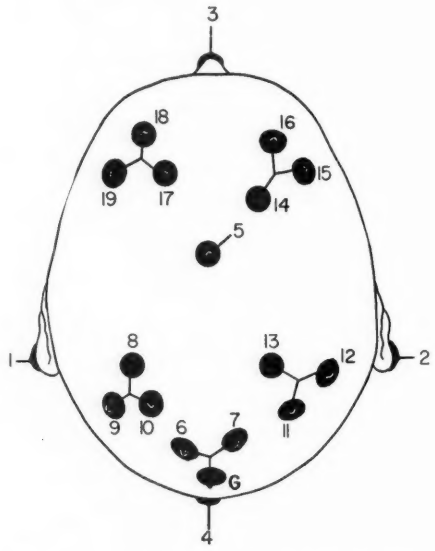

Fig. 1.—Diagrammatic placement of reference electrodes as seen from the top of the head. Number 4 represents the position of the occipital electrode. Number 5 represents the position of the vertex electrode. Electrodes 6 through 19 constitute the generalized reference. The ground electrode placement is represented by *G*.

Active electrodes were placed on the surface of the skin over the left temporal and left digastric muscles. The reference electrodes (a total of nineteen) were placed as follows: one on the left ear lobe, one on the right ear lobe, one on the tip of the nose, one on the occipital portion of the cranium, one on the top of the head (vertex), and fourteen placed at various points on the cranium (Fig. 1). Thus, it was possible to compare activity of the left temporal and left digastric muscles when these were recorded using as a reference any one of the following series: (1) the ear lobe on the ipsilateral side; (2) the earlobe on the contralateral side; (3) the tip of the nose; (4) both ear lobes (2-point reference); (5) both ear lobes and the tip of the nose (3-point reference); (6) both ear lobes, the tip of the nose, and the occipital electrode (4-point reference); (7) both ear lobes, the tip of the nose, the occipital electrode, and the vertex electrode (5-point reference); and (8) a "generalized reference," standard in EEG, which utilizes four-

teen cranial electrodes connected together with resistors to provide a theoretical zero voltage point, plus one occipital electrode used to ground the patient.

Recordings were made to provide comparisons of these eight electrode reference combinations mentioned during each of six mandibular excursions. These movements were: (1) clench, (2) retrude, (3) protrude, (4) right lateral movement, (5) left lateral movement, and (6) uncontrolled opening.

All of the above were performed on each of five subjects. Since the recorder has only eight channels for simultaneously recording phenomena, fourteen recording sessions were necessary to test all of the various combinations of electrode placement.

Thus, a total of 480 recordings were made for this study. Direct comparison was made of the electrical activity of each reference electrode combination to the standard generalized reference on all electromyograms.

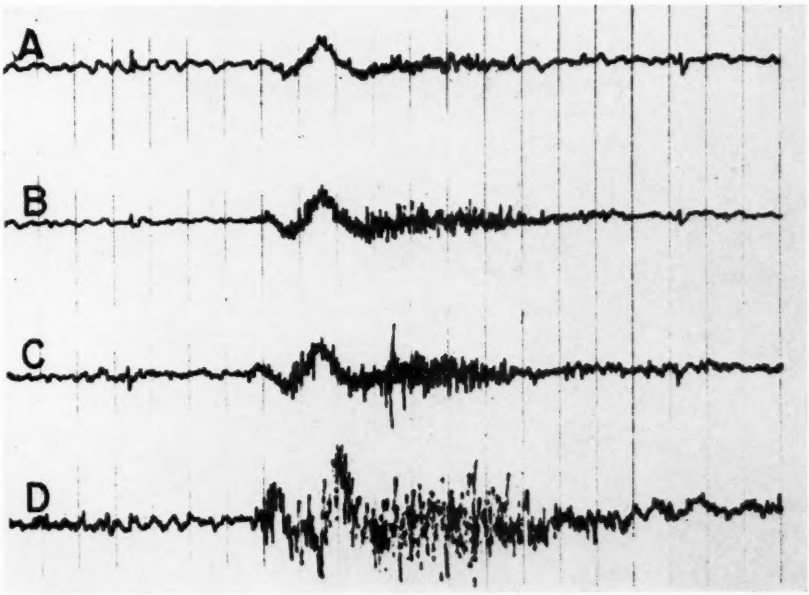

Fig. 2.—This shows the basis upon which the arbitrary values 0 to ±3 were assigned for the purposes of compiling Table I. The difference between *A* and *B*, *B* and *C*, or *C* and *D* was considered a +1 value. Conversely, the difference between *B* and *A*, *C* and *B*, or *D* and *C* was considered a −1 value. The difference between *A* and *C*, or *B* and *D* was assigned a +2 value; conversely, if comparison was made between *C* and *A* or *D* and *B*, a value of −2 was assigned. The difference between *A* and *D* or *D* and *A* was assigned a +3 or −3 value, respectively.

RESULTS

Examination of the physical system resulting in genesis of the potentials recorded in this study reveals that quantitative description of the results is relatively difficult (see Discussion). However, the desirability of at least semiquantitative tabulation is great. Therefore, the relative electrical activity of each record was assigned a value between 0 and ±3, on the basis of simple visual inspection. The

required comparisons of electrical activity in one recording situation with that in others were then made, and the results have been expressed as the numerical difference between the activities noted and those noted using the generalized reference, in the arbitrary units indicated. Typical records to which various values were assigned are shown in Fig. 2.

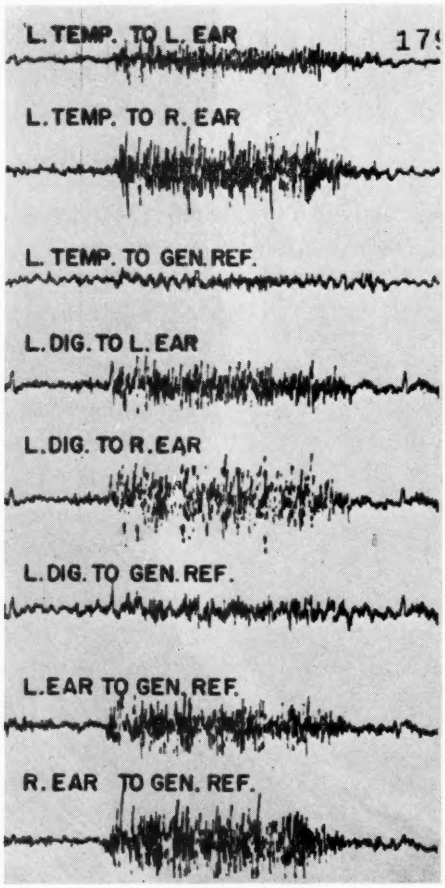

Fig. 3.—An electromyogram of a forward protrusion of the mandible. The activity from the muscles under study was referred to the ears separately and to the generalized reference. Note the great amount of electrical activity recorded for this movement when the temporal and digastric muscles were referred to each ear. Contrast this with the relative inactivity recorded from these muscles when referred to the inactive generalized reference. The amount of electrical activity recorded from the ears for this movement is seen when they are referred individually to the generalized reference.

Since it is impractical to list all of the values obtained in the hundreds of recordings made, we have expressed the results of the study in terms of the differences in electrical activity noted (first seven columns of Table I). Although subject-to-subject variation was relatively small, it was great enough that a comparison of absolute values in all cases is of little value. However, the differences between absolute values were quite consistent. For this reason, the individual values entered in Table I represent the differences, "plus" values meaning that

more activity was observed in the recording than that when the active electrode was compared with the general reference, and "minus" values meaning less than with the general reference. The numbers in parentheses indicate the number of subjects (out of a total of five) who showed the listed difference; the remaining subjects showed little or no difference.

Figs. 3, 4, and 5 show typical electromyograms for a protrusive movement of the mandible. Figs. 6 and 7, on right and left lateral excursions, respectively, show the common variations recorded on the electromyograms when active reference areas (ear lobes) are employed. All recordings were of this general nature, and the difficulty of quantitation is apparent.

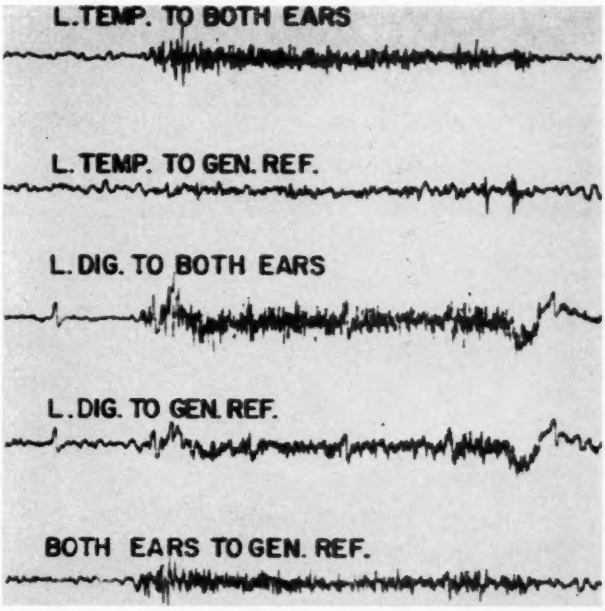

Fig. 4.—An electromyogram of a forward protrusion of the mandible. The activity from the muscles under study was referred to the combined ears and to the generalized reference. The activity recorded from these muscles for this movement when referred to the combined ears would appear to be at least moderate. Actually, when referred to the inactive generalized reference, this activity is very slight. Note the electrical activity present in the combined ears when they are referred to the generalized reference. The source of this electrical activity would be the external pterygoid muscles.

Space does not permit a detailed description of the findings derived from examination of Table I. However, it is possible to make a few generalizations which can help us in making conclusions regarding the validity of recording geometries. Some of these generalizations are:

1. The greater the number of electrodes included in the reference network, the more nearly comparable to the use of a general reference the reference arrangement becomes.

TABLE I.

REFERENCE		LEFT EAR	RIGHT EAR	NOSE	BOTH EARS	2 EARS + NOSE (3 POINTS)	2 EARS + NOSE + OCC. (4 POINTS)	2 EARS + NOSE + OCC. + VERTEX (5 POINTS)
Clench	Left temp.	same	same	same	same	same	same	same
	Left dig.	−2(4)	−2(4)	−2(4)	−2(5)	−2(4)	−1(3)	−1(1)
Retrude	Left temp.	−2(4)	−1(4)	−1(4)	−2(3)	−1(2)	same	same
	Left dig.	−1(2)	−1(2)	−1(4)	−1(3)	−1(3)	−1(2)	−1(1)
Protrude	Left temp.	+2(5)	+3(5)	+1(2)	+2(5)	+1(1)	+1(1)	same
	Left dig.	+2(5)	+3(5)	same	+2(5)	same	same	same
Right lateral	Left temp.	+3(5)	+2(5)	same	+2(4)	+1(1)	same	same
	Left dig.	+2(5)	+2(5)	−1(2)	+2(2)	same	same	same
Left lateral	Left temp.	+1(5)	+3(5)	+1(2)	+1(2)	same	same	same
	Left dig.	+1(1)	+2(3)	−1(1)	+1(1)	same	same	same
Open (uncontrolled)	Left temp.	+2(5)	+2(5)	−2(1) +2(2)	+2(4)	same	same	same
	Left dig.	same	same	same	+1(2)	same	same	same

2. For practical purposes, the results obtained with a 5-point reference electrode are identical with those obtained with the general reference.

3. In lateral excursions of the mandible, activity is greatest with single reference electrodes when the reference electrode is on the same side as the active muscle (external pterygoid muscle).

4. In regular openings, protrusive and retrusive movements, there is no significant difference when the single electrodes are placed on the midline (nose) but differences appear when the right and left ears are used separately as references.

5. When both ears are used in the reference, the results deviate considerably from those of the general reference, but less than a single ear reference.

6. Occipital, nose, and vertex electrodes have considerable influence on the zero stability of the reference electrode network.

DISCUSSION

For various reasons, surface electrodes are preferred for dental electromyography. It is not possible, using surface electrodes, to obtain the clarity and freedom from ambiguity which is associated with the use of coaxial needle electrodes. However, the coaxial needle technique is not altogether satisfactory since the activity recorded is necessarily that of one or at most a few motor units. These motor units may not be representative of the over-all activity of the muscle.

Surface electrodes provide activity recordings which are difficult to analyze from a purely physical point of view. For an illustration of the difficulties in-

volved in such analysis, we refer to Fig. 8. This diagram shows a cross section of the head, in which the tissues are differently classified as "poor" or "good" electrical conductors. Roughly speaking, current spread through tissues is such that the currents will flow through the good conductors, circumventing the poor conductors. Since voltage gradients are parallel to the lines of current flow, one can draw isopotential lines in a theoretical system such as that shown perpendicular to the lines of current flow. These isopotential lines are the dotted lines in Fig. 8.

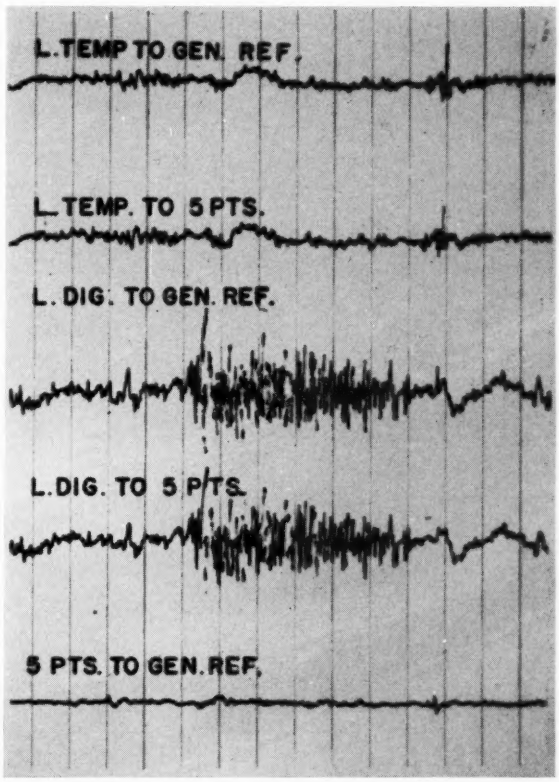

Fig. 5.—An electromyogram of a forward protrusion of the mandible. The activity recorded from the muscles under study appears to be identical whether the muscles are referred to a 5-point (nose, vertex, occipital, both ears) or to the generalized reference. Note the lack of activity when the five points are referred to the generalized reference.

It is apparent that the isopotential contours of Fig. 8 were arbitrarily drawn in and a true representation would require the construction and careful examination of a "phantom" head cross section. Also, such a cross section as this is necessarily two-dimensional, while the real situation is three-dimensional.

Nevertheless, Fig. 8 illustrates certain points important to the investigation at hand. For one thing, an active area in the external pterygoid muscle would be partly shielded from an ipsilateral temporal electrode by the ramus of the mandible, a part of the maxilla, etc. The placing of this shielding would also influence

the potentials seen at the ipsilateral ear lobe, but not, of course, to the same extent as it would influence the temporal electrode potentials.

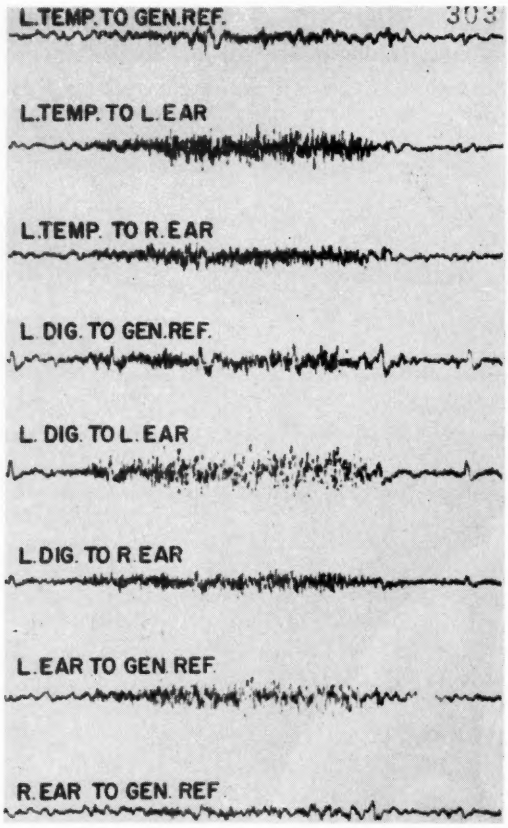

Fig. 6.—An electromyogram of a right lateral excursion of the mandible. The activity from the muscles under study was referred to the ears separately and to the generalized reference. The electrical activity recorded from the muscles is greatest when referred to the left ear which is on the side of the active muscle (left external pterygoid). It is less when referred to the right ear but the true electrical activity present is shown when the muscles are referred to the inactive generalized reference.

Thus, it is seen that if a temporal electrode could be compared with a "true" zero reference, its activity would be a quantitative indication of activity of muscles in the near tissues. This activity would be modified to some extent by the potentials originating in more distant tissue areas. Because of attenuation associated with potential spread through tissues of finite resistance, muscles on the contralateral side would exert a small influence, while those on the ipsilateral side would have great influence.

When the activity of a temporal electrode is compared with another, single electrode as "reference," the voltage of this reference electrode would summate algebraically with that of the active electrode (principle of superposition). This error may be either in the direction of augmentation or of detraction, depending on the geometry of placement of the electrodes.

It is apparent from this type of analysis that the use of single electrodes as references is fraught with much error. This deduction is verified by the experimental data summarized in Table I. Considerable augmentation or detraction are present when activity of a single electrode is compared with either left or right ear, especially when muscles near the two electrodes are used. When the muscle primarily producing lateral excursion of the mandible (external pterygoid) is active, an augmentation from its electrical field is seen in records from other muscles. This augmentation is greater when the reference electrode is placed

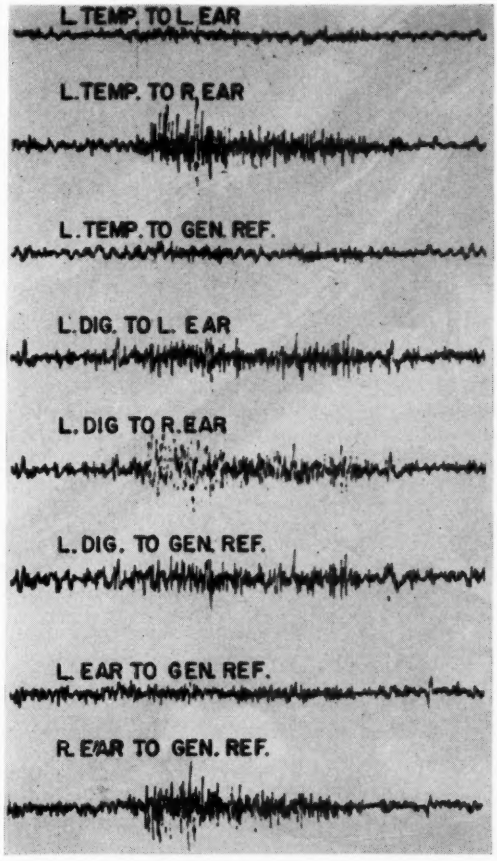

Fig. 7.—An electromyogram of a left lateral excursion of the mandible. The greatest amount of electrical activity recorded here is seen when the muscles under study are referred to the right ear, the side of the contracting external pterygoid muscle. Compare with Fig. 6 the amount of activity recorded from the separate ears when referred to the generalized reference. The electrical activity actually present in the muscles is seen when they are referred to the basically inactive generalized reference.

within the immediate area of this electrical field (ipsilateral ear lobe) and is less when the reference electrode is placed contralaterally to the active external pterygoid muscle. It is interesting that in a clench, where muscles in the upper jaw region are active, an ear lobe reference in this same general region shows ac-

tivity which is similar to that of a multielectrode reference. However, when the electrical activity from the digastric muscle on a clench is referred to a single ear lobe, there is some detraction. Exactly the reverse is true when the digastric muscle is active, as in an uncontrolled opening (an augmentation occurs).

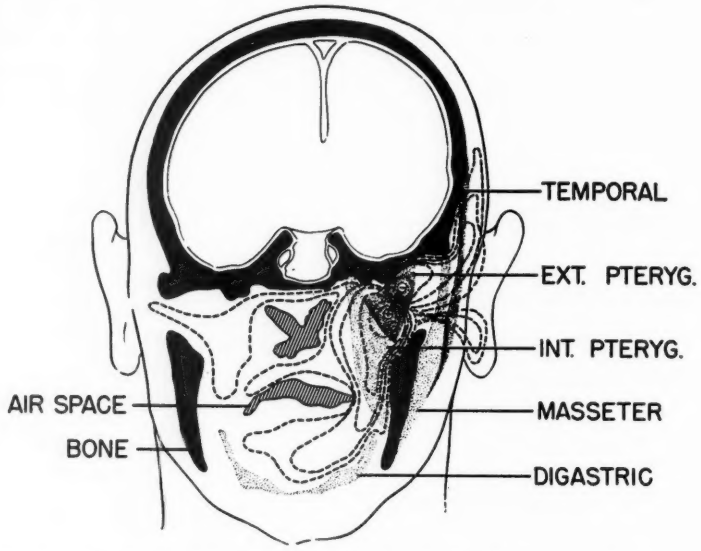

Fig. 8.—Diagrammatic frontal section of the head, showing some of the many pathways by which small electrical potentials may spread through tissues. Air spaces are nonconductors. Bone is a relatively poor conductor. The soft tissues are relatively good conductors due to the ionic content of the tissue fluids.

For practical purposes, the most important finding in Table I is that the greater the number of electrodes used in the reference electrode, the less deviation from a true "reference" occurs. In electroencephalography, it is well recognized that a reference electrode which contains many individual electrodes provides a nearly true zero voltage point.[8, 9] These electrodes are connected together by resistors which are an order of magnitude greater than the electrode-electrode resistance. As currents flow in these resistors, the voltage drops in the resistors are such that, at the common terminus, there is virtual cancellation of potentials and what amounts to a nearly "true zero" exists.

Because electromyograms are relatively rich in high frequency components, the analyst of this system would have a resort to the use of impedance concepts for a full understanding. This would involve complex transfer functions, and augmentation or cancellation would involve time dependency as well as pure resistance. For practical reasons, we do not intend to go into such analyses.

In dentistry, the time required for placement of a great many electrodes and the "messiness" of placing electrodes in the hair, preclude the use of such a "generalized reference" as that used in electroencephalography. However, our data indicate that comparable recordings can be obtained with a five-electrode system, where only two (vertex and occipital) are in hairy regions. For that matter, a four-electrode reference, in which the vertex electrode is abolished, provides a tracing with only minor errors.

It is apparent from these data and from the deductive reasoning disclosed previously that EMG recordings taken with single reference electrodes do not provide accurate data. Thus, this practice should not be used in the future, and data reported in the past using such techniques should be re-examined critically before conclusions based on them are accepted.

SUMMARY AND CONCLUSIONS

A study of the effect of electrode geometry on the validity of electromyographic tracings in dental situations has been made. This study included recordings made on five subjects, using each of two active electrodes and eight reference electrode arrangements, ranging from single electrodes to a fourteen-point "generalized reference," and six standard jaw movements. The conclusions drawn were as follows:

1. Geometric spread of potentials in the tissues of the head is such as to produce augmentation and/or cancellation when single electrodes or small number combinations of electrodes are used as references.

2. The greater the number of electrodes included in the reference combination, the more nearly valid are the tracings from an active electrode.

3. A five-electrode arrangement, described in the text, provides a nearly error-free reference. A four-electrode reference is subject to slight error. These reference arrangements have some practical advantage over the 14- or 18-point references used in electroencephalography.

4. Even when a valid reference electrode is used, an active electrode will "see" activity from multiple tissue areas when movements involve more than one muscle. Thus, interpretation of dental electromyograms should recognize the importance of head geometry.

REFERENCES

1. Perry, H. T., and Harris, S. C.: Implications of Myographic Research, Angle Orthodont. **26**:179-188, 1955.
2. Geltzer, Bernard: A Study to Develop a Standardized Method by Which Electromyographic Data May Be Recorded for Serial Evaluation, Bulletin of Northwestern University **54**:4-10, 1953.
3. Grufield, B. E., and Wyke, B. D.: Electromyographic Studies of Some of the Muscles of Mastication, Brit. D. J. **100**:129-143, 1956.
4. Moyers, R. E.: An Electromyographic Analysis of Certain Muscles Involved in Temporomandibular Movement, Am. J. Orthodontics **36**:481-515, 1950.
5. Jarabak, Joseph R.: An Electromyographic Analysis of Muscular and Temporomandibular Joint Disturbances due to Imbalances in Occlusion, Angle Orthodont. **26**:170-190, 1956.
6. Pruzansky, S.: The Application of Electromyography to Dental Research, J.A.D.A. **44**:49-68, 1952.
7. Hickey, J. C., Woelfel, J. B., and Rinear, L.: The Influence of Overlapping Fields on the Interpretation of Electromyograms, J. Pros. Den. **7**:273-281, 1957.
8. Offner, Franklin F.: The EEG as Potential Mapping: The Value of the Average Monopolar Reference, Electroencephalography and Clinical Neurophysiology **2**:213-214, 1950.
9. Goldman, Douglas: The Clinical Use of the "Average" Reference Electrode in Monopolar Recording, Electroencephalog. & Clin. Neurophysiol. **2**:209-212, 1950.

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A SUPPORTIVE-TYPE PROSTHETIC SPEECH AID

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THE CONSTRUCTION AND EVALUATION of a specially designed prosthetic speech aid for a patient with extensive pharyngeal and total palatal paralysis will be discussed. The paralysis resulted from a ten-day illness from bulbospinal poliomyelitis. The design of the prosthesis employs the principle of palatal elevation as a means of decreasing the lumen of the palatopharyngeal valve in speech.

SPEECH HISTORY

A brief examination of the patient's speech was undertaken while he was still hospitalized immediately prior to discharge. At that time, he was able to produce a weak, breathy voice of a few seconds' duration. His pitch range was restricted to three or four tones, and his voice was consistently hypernasal. Speech intelligibility was poor, but it was improved when his nasal passages were closed manually at the nostrils. Some tremor of the tongue and lips was noted, and the tongue deviated slightly to the left on protrusion. Weakness of the lips was evident on the left side with a tendency for saliva to collect at the left corner of his mouth. His history indicated normal speech and language up until the time of his illness.

The patient was referred to the speech clinic and, at the time of this examination, there had been no decided improvement in his speech since the evaluation two weeks earlier. His voice was breathy and weak in volume, and the quality approximated that of a severe cleft palate speech. Speech intelligibility was poor. Tongue tip movements were inaccurate, and the consonants *t* and *d* were generally made with the tip of the tongue depressed and the tongue blade contacting the maxillary anterior teeth and alveolar ridge. The patient complained that the tongue tip tended to protrude interdentally during speech.

Owing to the paralysis of the palatopharyngeal musculature, the patient was unable to achieve adequate oral pressure for the clear articulation of consonant sounds. This factor, added to the hemiparesis of the tongue and lips, resulted in a distortion of most of the consonant sounds. Efficiency of the palatopharyngeal valve as tested by the spirometer was less than 40 per cent.† He was able to drink water

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†In this test, efficiency of the valve is estimated by dividing the patient's "vital capacity" (nostrils open) by the vital capacity achieved when the nostrils are manually occluded. For a person with a normal palatopharyngeal valve, the index is 1.00, indicating an efficiency of 100 per cent. Although the test requires some clinical interpretation, it is useful as an index of the degree of palatopharyngeal function for blowing.

through a straw, but with some difficulty. General recommendations for improvement of his speech included the use of a straw routinely in drinking liquids, the use of a glottal attack exercise to improve vocal cord function and phonation, and practice to extend the pitch range of his voice. He was referred to the local public school speech therapist in his home community for speech instruction.

Subsequent evaluation, following a period of speech therapy in the public schools, demonstrated some improvement in intelligibility. Lingual and labial paralyses were reduced, and his index of palatal efficiency had improved to about 80 per cent. The voice was still consistently hypernasal, and sibilant and plosive sounds were weak. Vocal loudness had improved and was considered adequate for average conversational conditions.

Further improvement in speech was effected at the speech clinic, but the essential defects of voice and articulation related to the palatopharyngeal deficiency persisted. The patient developed some compensatory valving by elevation of the dorsum of the tongue to express air from the oral cavity as in buccal speech. The general effect of this adaptation was not satisfactory. Problems of personal and social adjustment were found in working with him. There were occasional moods of depression, hostility was expressed toward other patients in his therapy group, and he resisted practice for speech improvement. He was referred for psychologic evaluation, vocational testing, and counseling. Consideration of palatopharyngeal surgery was deferred on the recommendation of the oral surgery department.

PROSTHETIC TREATMENT

An oral examination revealed a flaccid, low-draped soft palate incapable of movement during speech or swallowing. No reflex was elicited. Pharyngeal movement was inadequate, with greater movement noted on the right lateral and posterior pharyngeal wall as compared to the opposite side. Visual examination of the neck and trunk revealed gross atrophy of the neck muscles on the left side. The patient experienced some difficulty in the swallowing of food, and he consumed large quantities of liquid to help wash down each mouthful of food. The major complaints concerning speech were an objectionable hypernasality and decreased speech intelligibility.

The first speech aid which was constructed resembled a fixed bulb-type obturator used for postsurgical cleft palate patients (Fig. 1). The patient was unable to tolerate this prosthesis. The palatal strap interfered with the tongue during speech and deglutition, and the obturator created great discomfort in the pharynx. The benefit to speech was negligible.

A second prosthesis that displaced the soft palate in an upward direction approximating a position which the velum would attain during normal function was constructed (Figs. 2 and 3). The elevated positioning of the palate was not resisted by any downward pull of the glossopalatine or pharyngopalatine muscles. It was postulated that an elevation of the palate to a position of near closure might possibly permit the restoration of enough function of the palatopharyngeal valve to effect closure. In any event, the lumen would be greatly reduced, although it would permit nasal breathing.

The speech aid was constructed of plastic providing full coverage of the hard palate. Retention was achieved with four wire retainers which were placed on the right and left first bicuspids and the right and left first molars. The soft palate

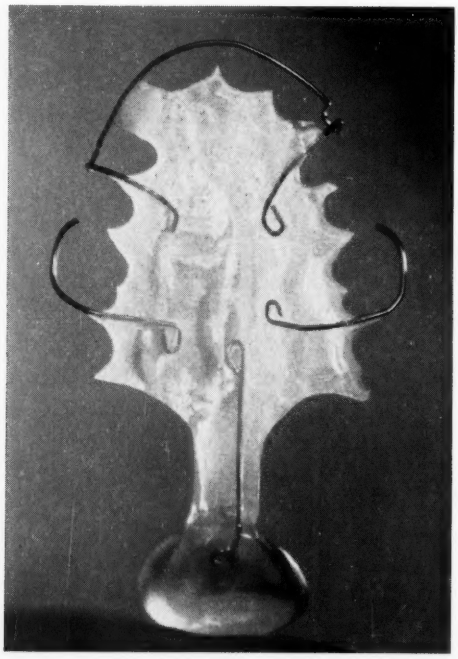

Fig. 1.—The fixed bulb obturator which was not tolerated by the patient.

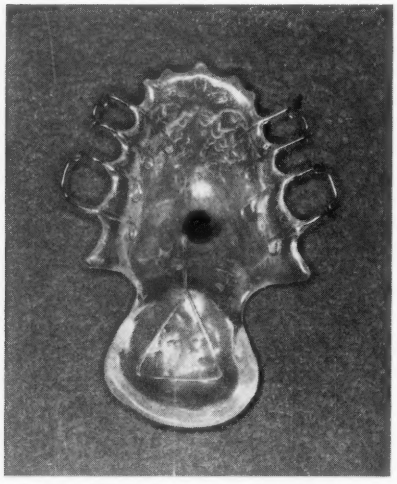

Fig. 2.—The second prosthetic speech aid which was constructed for soft palate paralysis. It consists of a complete hard palate coverage with wire retainers and a soft palate extension that lifts the soft palate to the approximate height which the velum normally attains during speech function.

was elevated by means of a broad convex plastic extension from the portion of the appliance covering the hard palate. All surfaces of the soft palate extension were molded to the contours of the soft palate when elevated.

The lateral profile cephalogram (Fig. 4) demonstrates the low drape of the soft palate, leaving a wide space in the velopharyngeal port between the soft palate and the posterior pharyngeal wall. The only voluntary movement that the patient could demonstrate in the soft palate was a slight quiver of the uvula.

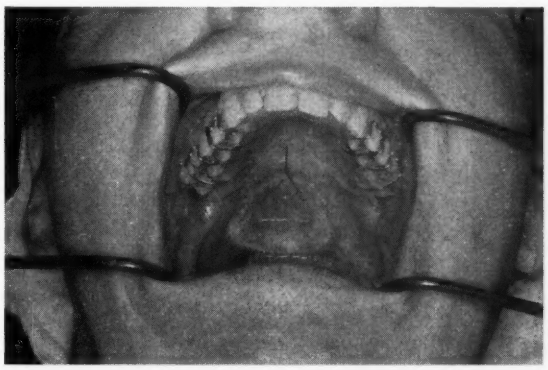

Fig. 3.—The appliance in the patient's mouth.

Fig. 4.

Fig. 5.

Fig. 4.—A lateral profile cephalogram showing the low-draped soft palate and a wide opening in the velopharyngeal port.

Fig. 5.—A lateral profile cephalogram showing the elevation of the soft palate by the prosthetic speech aid.

The lateral profile cephalogram with the appliance in place (Fig. 5) demonstrates the elevation of the soft palate by the prosthesis. The tracing of the profile cephalogram compares the two positions of the soft palate (Fig. 6). The apparent contact of the soft palate with the posterior pharyngeal wall is an artefact brought about by the posterior and lateral wall of the pharynx superimposed over the soft

palate when projected on a flat surface. In actuality, there is an air space of approximately 3 mm. that can be observed clinically between the soft palate and pharynx. Observations and tests of palatopharyngeal function during speaking and swallowing did not demonstrate sufficient movement in the posterior and lateral pharynx to make a positive contact with the soft palate as elevated by the prosthesis. Passavant's pad was not observable in the pharynx during phonation or under the influence of mechanical stimulation to the tissues.

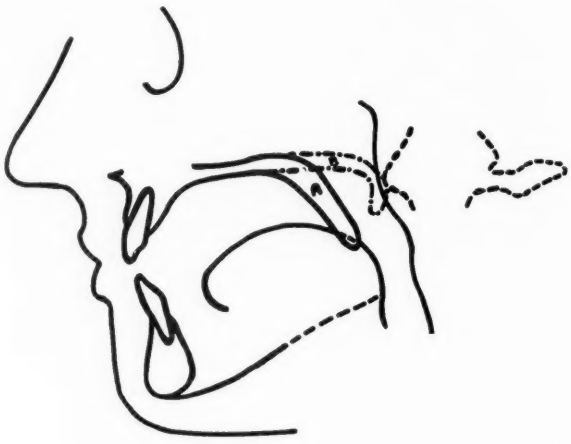

Fig. 6.—Tracings of lateral profile cephalograms showing (*A*, solid line) the position of the soft palate in repose and (*B*, dotted line) the position of soft palate as elevated by the speech aid.

This supportive speech aid was worn by the patient for more than one year. The patient reported no discomfort from the prosthesis. The problems of retention, the possibility of tooth movement of the abutment teeth, and injury to the soft palate as a result of pressure from the palatal section of the appliance were not demonstrated clinically over this period. The only inconvenience noted was that the patient did not wear the speech aid when eating, as it made swallowing more difficult. This is attributed to the fact that the patient developed a compensating movement of the tongue in swallowing in order to adapt to the pharyngeal and palatal paralysis.

Following this trial period, a more permanent type of prosthesis was constructed (Figs. 7 and 8), as there had not been sufficient return of muscle function to enable the patient to produce speech approximating normal quality without a speech aid. In construction of the permanent-type prosthesis, the retentive portion of the appliance utilized a cast metal framework with wrought wire retainers on the right and left first bicuspids and the right and left first molars. The portion of the appliance supporting the soft palate was constructed of plastic.

SPEECH EVALUATION OF PROSTHESIS

An instantaneous improvement in speech was noted after the speech aid was placed in the patient's mouth. Distinctness of consonant articulation was greatly

improved. The hypernasality was considerably reduced, and the quality of the hypernasality was changed from a "cleft palate" type to one resembling hypernasality of a "normal" speaker with a slightly relaxed palatopharyngeal valve.

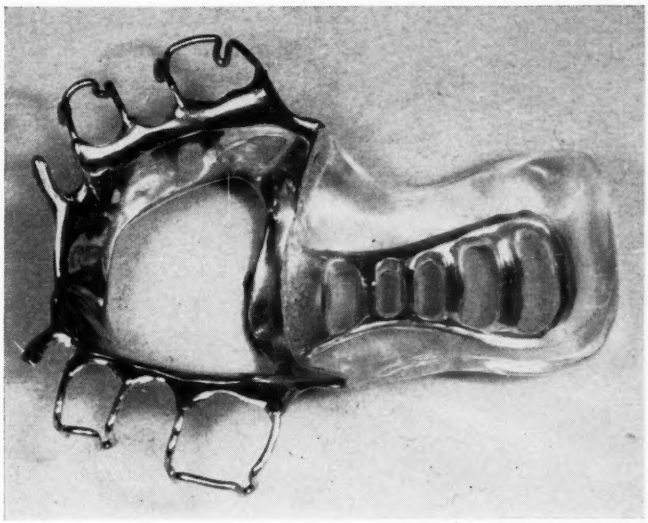

Fig. 7.—A prosthetic speech aid for soft palate paralysis. The retentive portion is a cast metal frame with wrought wire retainers and the soft palate supporting section is plastic.

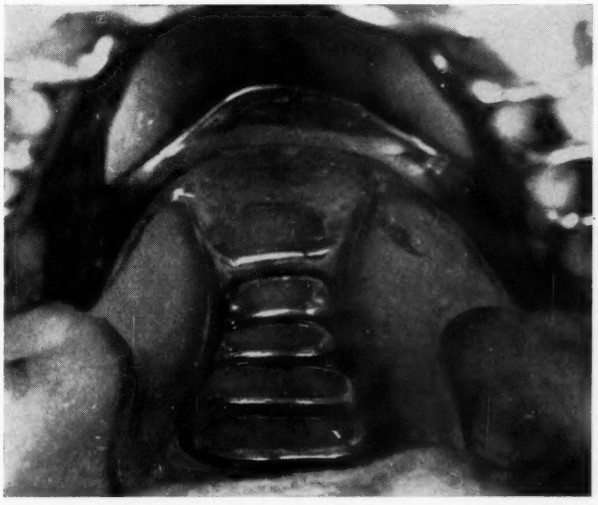

Fig. 8.—The prosthetic speech aid for soft palate paralysis in place in the patient's mouth.

Evidence of the effect of the prosthesis upon the patient's speech is shown in the sound spectrograms (Fig. 9). The sentence used is "Buy baby a bib," displaying the consonant sound *b* in initial, medial, and final positions in the words of the sentence. No nasal sounds normally occur in this sentence. Although the sample

without the appliance is a fraction of a second longer than the one with the appliance in place, the comparable vowel and consonant portrayals can be easily identified (Fig. 9).

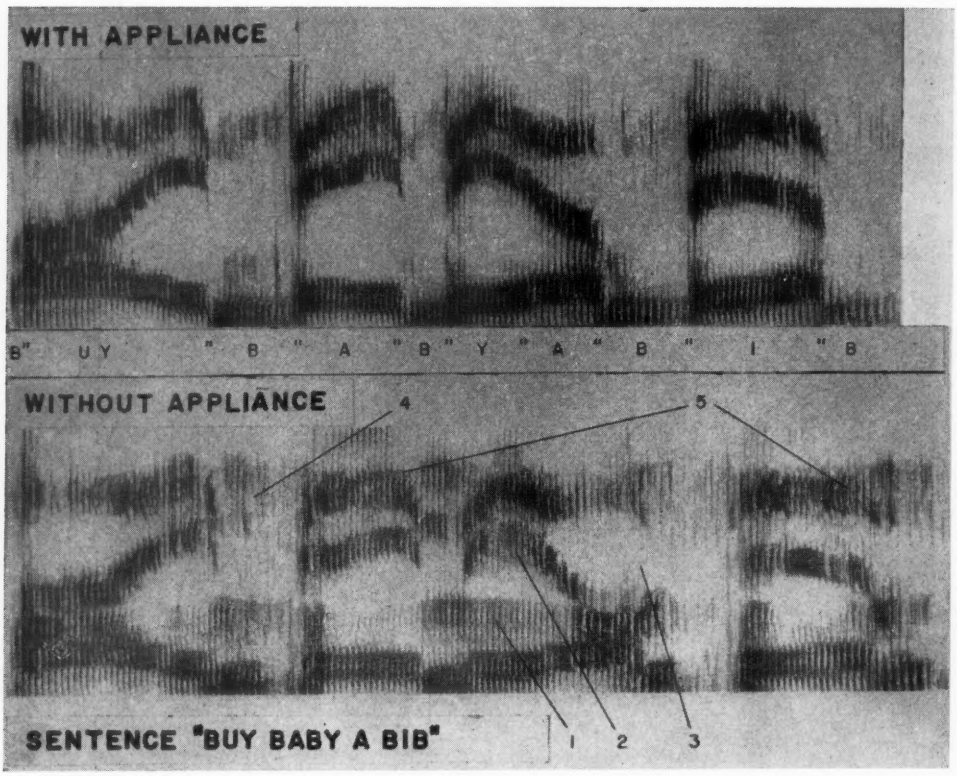

Fig. 9.—Sound spectrograms of the patient's speech. The top patterns, made with the supportive appliance in place, display a relatively normal "nonnasal" speech sample. The bottom patterns, made without the supportive appliance, show characteristics which have been observed in severely hypernasal speech. The approximate location of the phonetic elements is indicated by the subscript under the top pattern. The boundaries of the consonants and vowels are indicated by the quotation marks. The factors which typically identify hypernasality in these patterns are indicated in the lower spectrogram by number as follows: *(1)* the appearance of additional formants where they do not ordinarily occur in nonnasalized utterances of that vowel by a given speaker, *(2)* alteration in the width and intensity of the primary formants which characterize vowels, indicating a deterioration in the quality of the vowels in hypernasal speech, *(3)* loss or deterioration of sharply defined consonant boundaries, *(4)* additional vertical striations (random noise) indicating frictional emission of air through the nasal passages, and *(5)* atypical resonance bar movements. This factor is partially attributable to a deficiency in oral air pressure due to inadequate palatopharyngeal valving.

The acoustic spectrogram presents a visual display of sound patterns in which the horizontal axis represents time (approximately two seconds in the example illustrated), and the vertical axis represents frequency range (approximately 70 to 3,500 c.p.s.). Variations in relative loudness are shown in pattern densities of black and gray over an intensity range of about 12 decibels. The dark portions of the patterns record the more intense sounds; the weak intensities are registered in the light gray markings. The vowels and vowel-like components of the speech are

displayed by the wide dark "formant" bands which indicate areas of reinforced vocal resonance of approximately 300 cycle widths. Consonants are generally represented in the vertical striations. The "gaps" indicate, respectively, the audible fricative sounds which result from a constriction of the air blade and the momentary silences which characterize the intermediate implosion-explosion phase of the plosive consonants. The presence of voicing, as in the voiced consonant (*b* in these speech samples), is indicated by the presence of a formant on the base line of the acoustic spectrograms.

In general, these patterns show distinguishable differences between the examples of severely hypernasal and mildly hypernasal speech of this patient. The distinctions are ones which have been previously noted by Bloomer and Peterson[1] to characterize spectrographic comparisons of hypernasal and normal (nonnasal) speech. The effectiveness of the speech aid is shown by the fact that the acoustic spectrogram made when the appliance was in situ closely resembles that of a normal speaker. The pattern made without the appliance shows characteristics which are found in severely hypernasal speech (Fig. 9).

The patient is now enrolled as a student in the College of Engineering and takes a normal part in college life. The attitudes of depression which were noted during his speech instruction have apparently disappeared. Speech is adequate for average social communication, although a mild hypernasality still persists in connected discourse.

SUMMARY

The design and evaluation of a special speech aid is described as constructed for a patient who had bulbospinal poliomyelitis resulting in almost complete pharyngeal and palatal paralysis. The appliance elevates the palate to a position approximating that of normal retraction, thereby narrowing the lumen of the palatopharyngeal valve.

The degree of elevation and retraction of the palate accomplished by the supporting prosthesis represents an adjustment to several requirements: (1) a reduction in palatopharyngeal lumen needed to decrease hypernasality and increase oral pressure for consonant articulation, (2) the preservation of an airway to provide for comfortable nasal breathing, (3) the avoidance of undue stress upon the supporting teeth as the appliance resists the natural elasticity and weight of the palate in elevation, and (4) the absence of injury to the soft palate as a result of pressure from the supporting portion of the palatal section. The patient has worn a speech aid of the type described over a period of more than two years, indicating that the requirements of construction and wearability have been met.

The improvement in the patient's speech is demonstrated by portrayal through "visible speech" patterns in which the speech of the patient is shown to approximate that of a normal speaker when the appliance is in situ.

REFERENCE

1. Bloomer, H. H., and Peterson, G. E.: A Spectrographic Study of Hypernasality, Abstract, The Cleft Palate Bulletin **5**:5-6, 1955.

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A PROSTHETIC AID TO EARLY ORTHODONTIC TREATMENT

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EARLY ORTHODONTIC TREATMENT is important, especially for the cleft palate child. This article will present a technique which is of unique value for children who are living away from orthodontic centers. The appliance is designated as a "guide plane."

By the time the primary dentition of a child with a cleft lip and palate has completely erupted, the cleft lip has been repaired and, in most cases, the cleft of the palate has been repaired also. At this time, the alveolar process on the cleft side becomes attracted to the midline anteriorly with the tuberosity on the same side serving as a fulcrum. If the cleft is bilateral, both alveolar processes rotate toward the mid-line anteriorly, and each tuberosity serves as a rotation point for its respective palatal migration. As a result, the alveolar processes form a wedge behind the premaxilla, and the premaxilla becomes excluded from the dental arch. The constant elastic pull of the closed lip and cheeks and of the newly closed hard palate is responsible for this deformity. A child about two and one-half years of age is a little too young for active orthodontic therapy to be instituted.[1]

FACIAL GROWTH IN RELATION TO OCCLUSION

Active growth of the face in width and depth precedes eruption of the teeth. Most of the growth of the face in height and width occurs after the eruption of the first permanent molars. Davenport[2] and Hellman[3] have shown that the face grows relatively more in height and depth than in width. Growth of the face in width takes place on the free surfaces of bones by apposition and by the development of the lateral walls of the palate.

When the primary dentition has completed erupting, and prior to the erupting of the first permanent molars (Stage II-A to Stage II-C, Hellman[3]), the transverse dimension (width of the face) reaches four-fifths of its completed adult dimension.[4, 5] Children with an abnormal occlusion show a tendency toward a narrower face width. Continued nasal and maxillary development and growth depend upon proper respiratory function, while that of the mandible depends on masticatory function throughout the growth period.

MUSCLES OF MASTICATION

The closure of the jaws is accomplished by the action of (1) anterior fibers of the temporal muscles which pull upward, (2) the masseter muscles which pull

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upward, forward, and somewhat laterally, (3) the internal pterygoid muscles which pull upward and somewhat mesially, and (4) the posterior fibers of the temporal muscles which help to pull the condyles back in the glenoid fossae.[5]

These muscles develop forces with this prosthetic device in place which create pressure against the maxillary teeth and the alveolar processes. The pressure exerted is in the nature of a slow rubbing action. The patient clenches the jaws and uses the muscles of mastication to force the inclined planes of the splint against the maxillary teeth that are in lingual version. The child performs this biting exercise at intervals of 20 minutes or a total of 2 to 3 hours per day. A timing device may be used with the exercise.

A CLINICAL OBSERVATION

The measurement from the distal surface of the lower primary second molar to the mesial incisal angle of the lower central incisor remains fairly stable in growth relation up to 8 or 9 years of age. With this in mind, we consider these teeth and the upper borders of the alveolar processes of the mandible to be a good base for supporting a prosthetic device which will in turn guide the upper teeth and the maxillae into a more normal position.

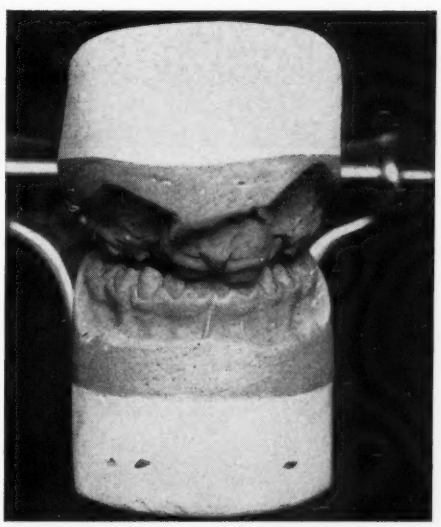

Fig. 1.—The casts mounted on an articulator with the vertical dimension of occlusion opened preparatory to the construction of the guide plane.

GUIDE PLANE CONSTRUCTION

Accurate impressions of the upper and lower teeth are made and poured in stone. The casts are occluded and mounted on an articulator. The vertical dimension of occlusion is increased 3 to 4 mm. (Fig. 1). Two thicknesses of baseplate wax are molded over the lower teeth and gums of the lower casts. The buccal and

lingual borders of the baseplate wax are extended 2 to 3 mm. below the gingival margins of the teeth. A wax guide plane is built onto the wax base starting from the buccal cusps of the lower teeth. It is built to slope upward and inward to engage

Fig. 2.

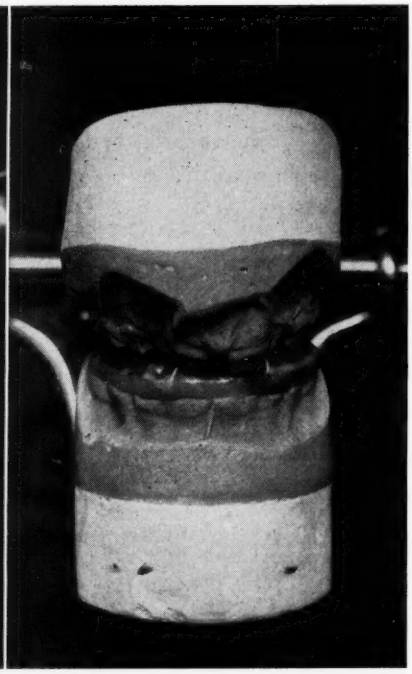

Fig. 3.

Fig. 2.—The cast silver incline planes are waxed to position on the lower teeth.
Fig. 3.—The articulator is closed with the lateral segments of the upper dental arch engaging the guide planes.

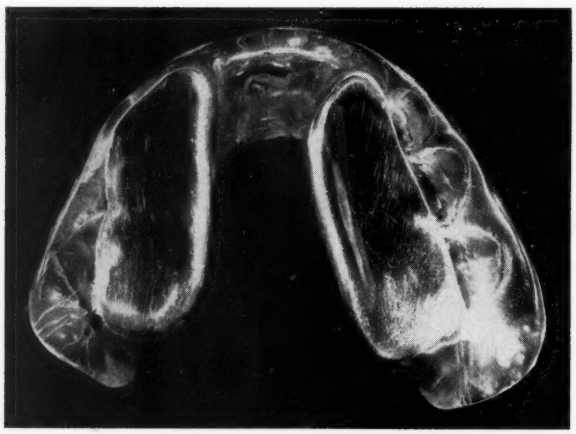

Fig. 4.—An occlusal view of the guide plane. Note the clear acrylic resin base and the cast silver guide planes.

the lingual cusps of the upper teeth that are in lingual version. The wax guide plane is removed from the wax base and cast in silver. The cast silver plane with its retention button is placed in the proper position on the wax base (Figs. 2 and 3), and the splint portion is processed in clear acrylic resin (Fig. 4). Clear acrylic resin is used so that any impingement of the splint on the soft tissue or on the erupting secondary anterior teeth may be observed (Fig. 5).

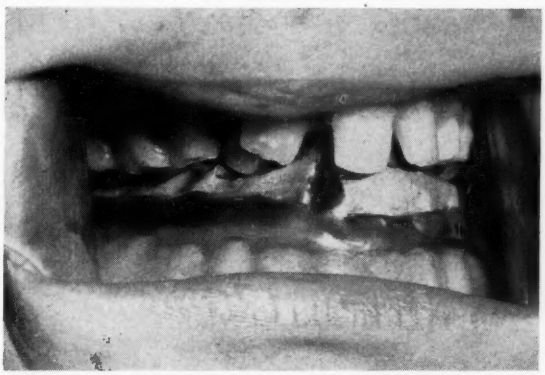

Fig. 5.—A guide plane appliance in the mouth. Note the guidance provided for the movement of the maxilla by the silver guiding surface which is attached to the transparent plastic splint covering the mandibular teeth.

ADVANTAGES OF GUIDE PLANE TREATMENT

1. The guide plane appliance assures the cooperation of nervous, unruly children.
2. It is simple to construct.
3. It can be removed easily for proper cleansing of the teeth.
4. It reduces the number of office visits as compared to fixed appliances. Inspections at 1- to 3-month intervals are adequate.
5. The amount of pressure applied is not likely to be excessive and it is intermittent.
6. The inclination of the guide plane is changed, when necessary, with a minimum of inconvenience and expense.
7. Early treatment with the guide plane has a favorable psychologic effect on the parents and the child.
8. The upper teeth in lingual version and locked in a cross-bite relationship with the lower teeth can be moved to their normal position.

CONCLUSION

When we are dealing with cooperative and reasonably intelligent parents, a passive type of orthodontic therapy may be employed by utilizing the guide plane appliance. The parents are carefully instructed as to the use of the appliance.

Early therapy with the guide plane in cleft palate children, and in other patients with underdeveloped upper dental arches, helps to minimize subsequent orthodontic treatment.

Patience must be exercised, as 3 to 12 months may be required to accustom the child to the use of the prosthesis, but the results of its use are very gratifying.

REFERENCES

1. Pierce, G. W., Terwilliger, K. F., Pennisi, Vincent, Jr., and Klabunde, E. Horace: Early Orthodontic Treatment in Cleft Palate Children, Plastic and Reconstructive Surgery **16**:8, 1955.
2. Davenport, C.: Changes in Headform, Science **89**:10, 1939.
3. Hellman, M.: An Introduction to Growth of the Human Face From Infancy to Adulthood, Int. J. Orthodontia **18**:777, 1932.
4. Salzman, J. A.: Principles of Orthodontics, Philadelphia, 1943, J. B. Lippincott Co., p. 125.
5. Salzman, J. A.: Principles of Orthodontics, Philadelphia, 1943, J. B. Lippincott Co., p. 159.

490 Post St.
San Francisco 2, Calif.

SIXTH ANNUAL ESSAY CONTEST

Sponsored by
THE AMERICAN DENTURE SOCIETY

Prizes will be awarded to the two senior dental students who submit the best essays on prosthetic dentistry in the sixth annual essay contest sponsored by The American Denture Society. The purpose of the contest is to stimulate technical writing by dental students.

The first prize is Five Hundred Dollars ($500.00) and the second prize is Three Hundred Dollars ($300.00).

RULES

1. The contest is open to all senior dental students of the United States and Canada.
2. Only two essays may be submitted from any one dental college. (It is recommended that each dental college conduct its own contest to determine the two best essays submitted by members of its senior class.)
3. Essays are to be on some phase of prosthetic dentistry and limited to a maximum of 3,000 words.
4. Essays must be worthy of publication in the JOURNAL OF PROSTHETIC DENTISTRY and must be prepared in a form which is satisfactory to the requirements of that Journal.
5. The original essay and one copy must be submitted for the use of the judges.
6. Essays must be typewritten, double spaced, on a good grade of white bond paper 8½ by 11 inches. Paragraphs must be indicated clearly by indentations, and generous margins must be allowed on each page.
7. Illustrations must conform to the standards of the JOURNAL OF PROSTHETIC DENTISTRY, if they are used. Only good glossy black and white photographic prints or drawings in India ink may be used. Each illustration should be mounted on a separate sheet of paper with the figure number and the legend typed on the paper beneath the illustration.
8. The form and punctuation of references must conform to the style used in the JOURNAL OF PROSTHETIC DENTISTRY. The references must be keyed to the text material.
9. The permanent address of the author must be at the end of the reference page.
10. The student has a free range in the choice of topics within the broad interpretation of prosthetic dentistry.

11. Essays will be judged on the basis of subject matter, neatness, composition, spelling, illustrations, charts and tables, number and accuracy of references, continuity of thought, and length of the essay.
12. The judges of the contest are members of a committee of The American Denture Society. The decision of the judges is final.
13. Essays are to become the property of The American Denture Society. None will be returned.
14. All essays submitted in the contest shall be clearly marked "Contest Essay" and shall be accompanied by a letter from the professor of prosthetic dentistry and/or the dean of the dental college from which they originate. This provision is to assure the authenticity of all essays entered in the contest.
15. Essays must be postmarked on or before July 15, 1958 and sent to:

Dr. Victor L. Steffel
Secretary, American Denture Society
College of Dentistry, Ohio State University
Columbus 10, Ohio

READERS' ROUND TABLE

Los Angeles, Calif.

Editor, The Journal of Prosthetic Dentistry:

In a recent article entitled "The Use of Rubber Base Impression Materials in the Construction of Inlays" [J. Pros. Den. 8:123-134, 1958] by Dr. Mortimer C. Davis, it was stated that, "Each die is soaked at least 12 hours in oil. . ."

It has been shown, through controlled experiments by Dr. Hollenback, et al., that soaking dies in oil softens the stone, especially in the most critical areas—the margins. Since the value of any technique depends upon the success of each step, the practice of soaking dies in oil should be discontinued.

Yours very truly,

Paul E. Goldman, D.D.S.

SPECIAL ANNOUNCEMENT

GLOSSARY RECOMMENDATIONS INVITED

The Glossary of Prosthodontic Terms, first edition, by the Academy of Denture Prosthetics, was published in the JOURNAL OF PROSTHETIC DENTISTRY, Volume 6, No. 2 (March), 1956. There has been much praise for the Glossary, which contains over 800 words and terms, and for the accomplishments of the Nomenclature Committee which coordinated the efforts of the Academy members and edited the publication. The Committee consisted of Carl O. Boucher, D.D.S., Chairman; Richard H. Kingery, D.D.S.; LeRoy E. Kurth,; D.D.S.; Victor H. Sears, D.D.S.; Vincent R. Trapozzano, D.D.S.; and Jack Werner, D.D.S.

In the preface to the first edition of the Glossary, the Nomenclature Committee stated:

"This, the first edition of the Glossary, is offered to the dental profession for its consideration. Since it is recognized that there are some terms which have not been included, and that some other terms and definitions which may be objectionable to some authorities have been included, revisions will be necessary from time to time. Constructive suggestions are invited, and these will be given thorough consideration in future editions. In its present form, this Glossary can serve as a good temporary standard."

Although constructive suggestions regarding revision of the Glossary were invited, very few have been received. This is a tribute to the skillful and meticulous manner in which the first edition was prepared.

The current Nomenclature Committee, consisting of Arthur R. Frechette, D.D.S., Chairman; Stephen G. Applegate, D.D.S.; and Frank C. Hughes, D.D.S., plan to present recommendations for revision of the Glossary to the Academy next April. For that reason, constructive suggestions are again invited. Revisions will involve the addition of terms not included in the original Glossary, deletion of certain obsolete or objectionable terms, and changes in definitions to clarify the meaning of some terms. It is particularly desired that suggestions for new or modified definitions include a proposed definition which is considered to describe clearly the term involved.

Communications should be addressed to the Chairman of the Nomenclature Committee, Captain Arthur R. Frechette (DC) USN, Bureau of Medicine and Surgery, Navy Department, Washington 25, D.C.

Reprints of *The Glossary of Prosthodontic Terms* may be obtained from Glossary Reprints, 400 Starks Bldg., Louisville, Ky. Price $0.50.

The Nomenclature Committee
Academy of Denture Prosthetics

BOOK REVIEWS

THE PRINCIPLES AND ART OF PLASTIC SURGERY. By Sir Harold Gillies, C.B.E., F.R.C.S., and D. Ralph Millard, Jr., M.D. Two volumes, 690 pages, 2,472 illustrations, 122 in color. Boston, 1957, Little, Brown & Company. Price $35.00.

This is not a textbook in the strict sense of the word; rather it is a fascinating, well-illustrated narration of the professional achievement and whimsical personal experience of an outstanding pioneer in plastic surgery.

The reader can be delighted or disappointed, depending on his attitude or material need, but without exception he will be interested.

The two volumes contain perhaps an incomparable wealth of clinical material. This is of particular value to the postgraduate dental and surgical practitioner who has himself encountered the difficult case and wrestled with its planned, multiple-staged reconstruction. The book abounds with "do's" and "don't's" of clinical management, and presented cases testify to the authors' authoritative qualifications. The text does not belabor minutiae. Broad principle is the theme. The peaks are discussed. Those who get lost in the valleys between are soon forgotten.

The magnificent surgery is skillfully portrayed, and the handsome format holds the reader's interest despite radical departure from the usual mode of presentation.

The foreword of Dr. J. P. Webster and the preface remark of the senior author reads as a condensed, modern history of plastic surgery. It is mentioned by both authors that several publishers refused their mode of presentation, and as one confronts the table of contents this is understandable. Upon turning the first page to find an impish, somewhat crude caricature, the reader feels that perhaps he has stumbled in error upon a high school yearbook.

However, the mood of the writers is contagious, and rapidly the anecdote, the puckish flavor, and the sheer pioneering genius that literally leap out from the countless cases catch the reader, and one finds the book difficult to lay aside. Of particular interest to the prosthodontist is the section on cleft palate rehabilitation. Along with Sir Kelsey Fry, Sir Harold Gillies presents an excellent review of cleft palate management and a specific broad discussion of the so-called Gillies-Fry procedure which these two physicians developed in 1927. This technique employs considerable prosthetic work.

It is of more than passing interest: nearly every so-called pioneer in reconstructive surgery (Gillies, Blair, Ivy) was blessed by the ingenuity of an outstanding dental colleague, or he himself was so qualified. Their recognized achievements serve to emphasize the persistent need for growth and positive cooperation rather than negative disparagement in what must be considered mutual problems.

Here is history written by a man who waded in its middle and dared to shoved convention aside. That this is accomplished with a twinkling eye and more than a touch of impishness there can be no doubt. The self-confidence and skill that enabled Sir Harold Gillies to become a top-seeded golfer and a dramatic, unshackled pioneer and leader in his chosen branch of surgery have enabled him to present his life's work in a radically different style. He, and perhaps only he, could get away with it. There lingers the question as to whether this were the best way to do it. Perhaps this remains poignant because so much was expected from the master. Knowing this, perhaps he decided to "leave them laughing and piqued with the thought that here is the best—go try and match it."

The text is presented in two volumes, 690 pages, and myriad illustrations and drawings. It is a must for every plastic surgeon's library. The dentist who finds his practice in any way allied will find the material informative and the book a fascinating adjunct to his library.

John C. Trabue

PERIODONTAL THERAPY. By Henry M. Goldman, D.M.D., F.A.C.D., Saul Schluger, D.D.S., and Lewis Fox, D.D.S., F.A.C.D., 565 pages, illustrated, indexed. St. Louis, 1956, The C. V. Mosby Company. Price $18.75.

This is a text in periodontology intended specifically for the clinician whether he be in practice or in training. Although a first edition, one could not overlook the similarity of this book to that of the third edition of H. M. Goldman's *Periodontia.* By omitting the sections on Anatomy, Histology, and Oral Physiology in the latter text, this book becomes devoted more exclusively to periodontal therapy and case management.

There is an excellent chapter devoted to suggestions for management of special problems such as faulty tooth anatomy, overlapping teeth, alteration in the mucobuccal fold, and other problems.

Several new techniques, which have not as yet been published elsewhere, are found in this text. However, the attribute which makes this book outstanding is the 100 plates of well-represented photographs and artistic drawings which render an actual clinical step-by-step procedure. These illustrations point up the discussion preceding it in each chapter. This is so well carried out that the plates actually represent an outline and summary of the treatments suggested by the authors. In addition, there are many other excellent preoperative and postoperative illustrations depicting various periodontal diseases and their response to treatment.

It is not the intent of the authors that the various methods of treatment presented should not be subjected to alteration or improvement, but that these methods represent the basic principles in theories and practices which have been accepted in periodontology.

The authors' organization of their material and the style of writing makes this book simple for the reader to follow and understand.

This book may be considered equal to, and quite possibly surpassing, the other periodontal texts, making it an excellent book to own.

Peter D. Ferrigno, D.D.S.

PROFESSIONAL PRACTICE MANAGEMENT. By B. C. Egerter, D.S.C., F.A.A.C. 504 pages, illustrated, indexed. New York, 1957, Pageant Press, Inc. Price $15.00.

This book is written in an easily read, down to earth manner. The author presents problems that have been encountered by all who are in professional practice. These problems are discussed fully, and various ways of handling them are presented. In the author's own words, the purpose of the book is to help the professional person "not only to gain economic security but also to recognize that such security is indispensable to the best professional practice."

Although this book is written by a chiropodist, and therefore many of the situations are drawn from chiropody, this in no way limits the use of the book to that field alone. The ideas and suggestions presented in PROFESSIONAL PRACTICE MANAGEMENT are certainly very applicable to the profession of dentistry, as well as to the other phases of the healing arts. The book is equally appropriate whether the reader has a successful, established practice or is still struggling toward that goal.

The subject matter is handled in a clear, concise manner throughout the entire book. The easy style of writing leads to fast reading without sacrificing the content. The illustrations are excellent and varied. There are simple drawings, charts, graphs, sample record sheets, as well as many full-page photographs and floor plans—all attractively done. The style of printing and binding and quality of paper are all good.

A wealth of information is covered in the book: such items as professional life plan, locations and types of practice, practice policy, patient contact, office assistants, appointment systems, patient control, office routine, practice development, fees and overhead, filing systems, collections, and accounting—to name only a few. A professional man, regardless of his special field, would find many subjects in this book that would benefit his own practice.

It is the opinion of the reviewer that the author has succeeded in his goal; and persons in all phases of the healing arts can profit from the subject matter and the intelligent way in which it is handled.

Charles E. Greiner, D.S.C.

NEWS AND NOTES

MEETINGS

American Association for Cleft Palate Rehabilitation, St. Francis Hotel, San Francisco, Calif., April 24 to 26, 1958.

For further information, write to Dr. D. C. Spriestersbach, Department of Otolaryngology, University Hospitals, Iowa City, Iowa.

Academy of Denture Prosthetics, Statler Hotel, Detroit, Mich., May 5 to 9, 1958.

Fifteenth Australian Dental Congress, Adelaide, South Australia, Feb. 23 to 27, 1959.

For further information, write to the Secretary, 15th Australian Dental Congress, 51 Grenfell St., Adelaide, South Australia.

ANNOUNCEMENTS

The University of Arkansas has announced the formation of an Institute for Post-Graduate Education in Dentistry. The purpose of the Institute is to promote broadly the advancement of dental education and all related phases of the arts and sciences that contribute directly to the profession. The Arkansas State Dental Association worked with University officials in designing the Institute and will aid in promoting the various scientific activities.

Indiana University, School of Dentistry, announces a course for technicians in Laboratory Phases of Fixed Bridge Construction, July 28 to Aug. 1, 1958.

The University of Alabama, School of Dentistry, announces the following refresher courses:

Complete Denture Prosthesis, Victor H. Sears, May 1 to 3, 1958.

Surgical Anatomy of the Head and Neck, Part I, Harry Sicher, May 17 to 19, 1958.

Etiology and Diagnosis of Pain of Dental Origin, Part II, Harry Sicher, May 20 and 21, 1958.

For further information and application, write to Dr. Arthur H. Wuehrmann, University of Alabama, School of Dentistry, Medical Center, Birmingham 3, Ala.

Emory University, School of Dentistry, announces the following postgraduate courses:

Pedodontics, Dr. Ralph L. Ireland and Staff, April 23 to 25, 1958.

Refresher Course in Immediate Denture Prosthesis, Dr. L. B. Brown, Dr. H. J. Harpole, Dr. J. C. Garland, and Dr. Parker E. Mahan, May 8, 1958.

For further information, write to Emory University, School of Dentistry, 106 Forrest Ave., N. E., Atlanta 3, Ga.

Temple University, School of Dentistry, announces the following postgraduate courses:

Advanced Surgical Techniques in Periodontal Therapy, Dr. Saul Schluger, April 21 to 25, 1958.

The Washed Field Technique in Accelerated Dentistry, Dr. E. O. Thompson, May 5 and 6, 1958.

Endodontics—Immediate Root Resection, Dr. Louis Grossman and Dr. Leonard Parris, June 3 to 7, 1958.

The Porcelain Jacket Crown, Dr. Joseph Ewing, June 11, 12, 18, 19, and 25, 1958.

For further information and application, write to Dr. Louis Herman, Postgraduate Division, Temple University School of Dentistry, 3223 North Broad Street, Philadelphia 40, Pa.

The Sterling-Rock Falls Rehabilitation Center, Rock Falls, Ill., announces a one-month course in maxillofacial prosthetics to be held Aug. 4 to 29, 1958.

For additional information, write to Edwin N. Cooper, Executive Director, Sterling-Rock Falls Rehabilitation Center, 303 West 2nd St., Rock Falls, Ill.

The Medical College of Virginia, School of Dentistry, announces the following postgraduate courses:

Oral Surgery, March 31 to April 2, 1958.

Periodontology, April 14 to 16, 1958.

Roentgenology, April 21 to 23, 1958.

For further information and application, write to Dr. H. T. Knighton, Medical College of Virginia, School of Dentistry, Richmond 19, Va.

Northwestern University Dental School announces the following postgraduate courses:

Use of Elastic Impression Materials, March 31 to April 2, 1958.

Complete Denture Procedures in General Practice, April 2 to 4, 1958.

Prosthetic Rehabilitation for the Cleft Palate Patient, April 7 and 8, 1958.

Clinical Features of Oral Lesions, April 16 to 18, 1958.

The Use of Drugs in Dental Practice, April 30 to May 2, 1958.

Diagnosis, Roentgenography, and Treatment Planning, May 5 to 7, 1958.

For further information and application, write to Director of Dental Postgraduate Study, Northwestern University Dental School, 311 East Chicago Ave., Chicago 11, Ill.

Tufts University School of Dental Medicine announces the following postgraduate refresher courses:

Diagnosis and Management of Occlusal Disharmonies, April 7 to 9, 1958.

Participation Course in Periodontology, April 14 to 18, 1958.

Hypnosis and its Clinical Applications, May 9, 10, and 12 to 14, 1958.

Complete Denture Prosthesis, June 2 to 6, 1958.

For further information, write to Director of Graduate and Postgraduate Studies, Tufts University School of Dental Medicine, 136 Harrison Ave., Boston, Mass.

The Ohio State University, College of Dentistry announces the following postgraduate courses:

Post-College Assembly, April 16 and 17, 1958.

Periodontics, Dr. John R. Wilson, May 5 to 9, 1958.

Review of Clinical Dentistry, Staff, May 12 to 16, 1958.

Pharmacology, Dr. William R. Kampfer, May 19 to 23, 1958.

For further information and application, write to Postgraduate Division, The Ohio State University, College of Dentistry, Columbus 10, Ohio.

The Veterans Administration Medical Teaching Group Hospital of Memphis, Tenn., announces that two rotating dental internships and one residency in Prosthodontics will be available for the year beginning July, 1958. Information and application forms may be obtained from the Chief of the Dental Service, Veterans Administration, Medical Teaching Group Hospital, Park Ave. and Getwell St., Memphis 15, Tenn.